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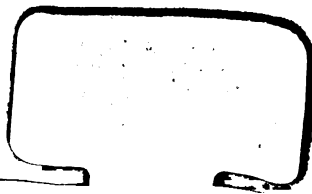


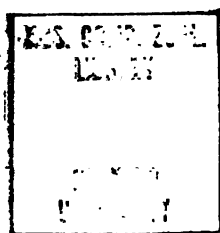
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RAPID CITY, SOUTH DAKOTA.

APRIL, 1900.

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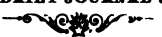
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RAPID CITY DAILY JOURNAL JOB ROOMS.


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Letter of Transmittal.

SOUTH DAKOTA SCHOOL OF MINES, }
RAPID CITY, April 4, 1900. }

SIR: I have the honor to transmit herewith a paper by Dr. Cleophas C. O'Harra on "A History of the Early Explorations and of the Progress of Geological Investigation in the Black Hills Region," and also one on "A Bibliography of Contributions to the Geology and Geography of the Black Hills region."

I submit them with the recommendation that they be published as Bulletin No. 4 of the School of Mines.

Respectfully,

ROBERT. L. SLAGLE,
President.

HON. H. H. BLAIR,
President Regents of Education.

CONTENTS.

	PAGE.
O'HARRA, CLEOPHAS C. A History of the Early Explorations and of the Progress of Geological Investigation in the Black Hills Region. (Plates I-VIII.)	7
O'HARRA, CLEOPHAS C. A Bibliography of Contributions to the Geology and Geography of the Black Hills Region.	45
INDEX to Names of Authors and Collectors.	87

A HISTORY

Of the Early Explorations and of the Progress of Geological Investigation in the Black Hills Region.*

BY CLEOPHAS C. O'HARRA.

Our knowledge of the Black Hills dates from near the beginning of the present century. The development of that knowledge, particularly as related to geology, may be conveniently divided into three periods, viz.: the period of fur-trading exploration; the period of military and geographical exploration; and the period of geological exploration. The first includes the early half of the century and is almost barren of scientific results. The second includes approximately the third quarter of the century beginning with the exploration by Dr. Evans in 1849, and closing with the military expedition under the command of Lieutenant-Colonel G. A. Custer in 1874. Several of the expeditions sent to the region during this period were accompanied by one or more geologists or topographers and in this way scientific information of much value was obtained. The third period begins with the Newton-Jenney survey in 1875 and extends to the present time. The Stanton military expedition was made later than this and indeed the Newton-Jenney survey was in the form of a military expedition, but since the explicit purpose of the latter was to investigate the geology and mineral resources of the region, which work was carefully and comprehensively done, the expedition may be fitly considered as marking the beginning of a distinct period.

The pioneer explorers of the northwest, Lewis and Clarke,

*A part of this paper was given as an address before the South Dakota Educational Association at its meeting in Hot Springs, August 3, 1899.

who made their famous exploratory trip to the mouth of the Columbia river during the years 1804-05-06, are credited with the first scientific mention of the Black Hills. The original map accompanying the report of this expedition represents the Black Hills as a single narrow mountain ridge extending from the South Fork of the Cheyenne river northwestward beyond the North Fork to the lower waters of Tongue river [Powder river?]. The report states that "Mr. Valle, a French trader, has ascended the Cheyenne for a distance of 300 leagues and reports that the Black Mountains are very high, covered with great quantities of pine and in some parts the snow remains during the summer." It may be well to state for the benefit of those not acquainted with the region that the distance here mentioned is apparently quite too great and that the Black Hills region as now understood does not contain peaks reaching above the snow line as might be inferred from the quotation given. During the early part of the century the term "Black Mountains" or "Hills" was indefinite. According to some the term was apparently used to designate only the mountains between the Laramie plains and the Forks of the Platte. This seems to have been the idea entertained by the early geologists, James and Englemann and others. Many considered the term as referring to the hilly region between the North Fork of the Platte and the Black Hills region as at present defined. This usage is indicated in Figure 2, Plate II, in which is shown a portion of an excellent map published in 1838 by Rev. Samuel Parker, who made extensive explorations in the Rocky Mountain region during the years 1835-36. More often the term was used to indicate two distinctly separated areas, designated as the Black Hills of Wyoming and the Black Hills of Dakota (or Nebraska). These referred to the Laramie Mountains and to the Black Hills as now understood. Plate IV, which is a reproduction of a portion of the map accompanying Lieut. Warren's "Report of Military Reconnaissances in the Dakota Country, 1855," indicates this usage although the Black Hills of Dakota are on this map made to extend too far to the northwest. The term "Black Hills" was in fact used loosely and

for many years included practically everything mountainous between the Missouri and the Rockies.

We are informed in Irving's Astoria that as early as the summer of 1811 a party under the direction of Wilson P. Hunt, one of the members of the American Fur Company, at the head of which was John Jacob Astor, while en route to the Columbia river from the old Arikaree village at the mouth of the Grand river on the Missouri, skirted the Black Hills on the north. They tried repeatedly to gain entrance into the Hills, but failed on account of the inaccessibility of the canyons where the attempts were made. The exact place of their approach is not known, but the supposition has been entertained by some that it was probably in the vicinity of Spearfish. Owing to this uncertainty the position of their route has been represented conjecturally on the accompanying route map, Plate I. The Hills are described as being "chiefly composed of sandstone and in many places are broken into savage cliffs and precipices, and present the most singular and fantastic forms."*

Notwithstanding this early acquaintance with the Hills, general information concerning the region was for many years extremely meagre. Possibly occasional visits were made into the Hills by parties or individuals, a fur trading post having been established about the year 1830 at or near the junction of the North and South Forks of the Cheyenne river,† but the observations were either not recorded or were of such doubtful accuracy as to be of little scientific value.

Important discoveries along the Missouri had directed the attention of geologists to the central and eastern parts of the state, but not until 1846-7 did they become especially interested in the mountainous western portion. Even then the interest of geologists in the Black Hills region did not originate in discoveries made in the Hills proper, but in the neighboring White River bad lands, the term "bad lands"

*This statement, especially the latter part, seems to refer more particularly to the "bad lands" north-northwest of the Hills.

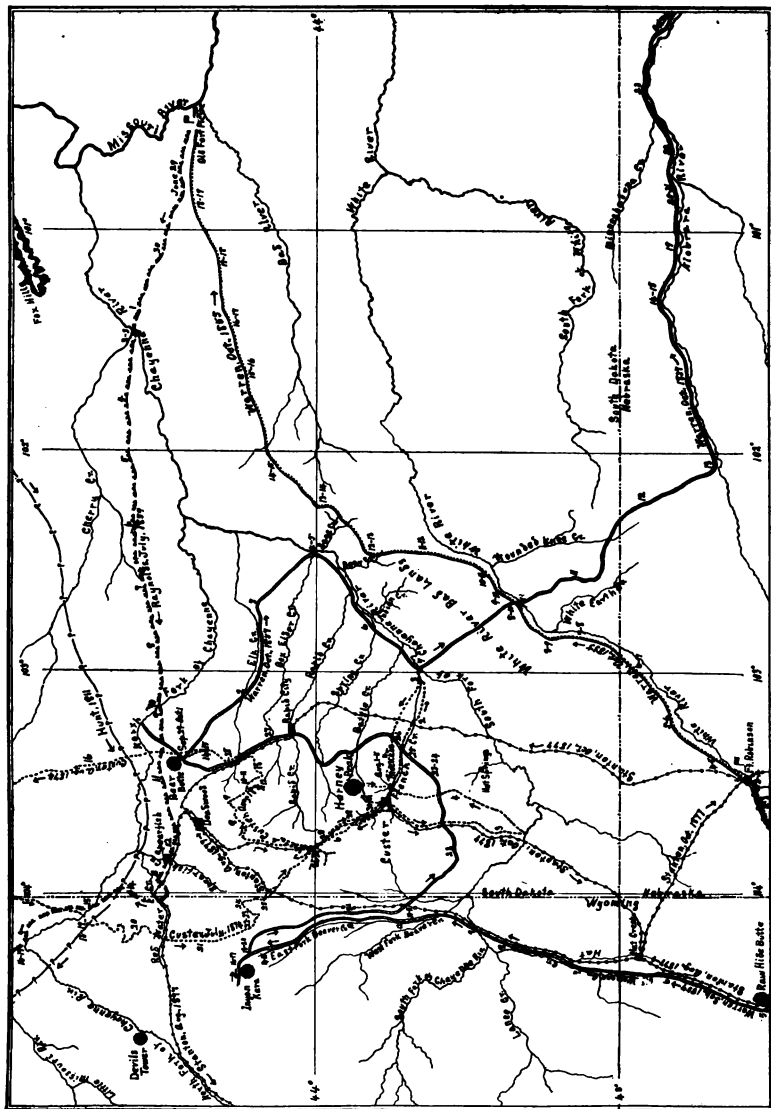
†Maguire, H. N. The Coming Empire, Sioux City, Iowa, 1878.

having been given by the early fur traders to this and similar areas on account of their difficulty of passage.*

Traders in the employ of the American Fur Company had at various times brought back interesting specimens of mammalian remains from the White River country and in 1846 Dr. H. A. Prout, of St. Louis, in this way came into possession of a fragment of the fossil lower jaw of one of these animals. The American Journal of Science, vol. II, pp. 288-289, 1846, in Miscellaneous Intelligence, under the head of "Gigantic Paleotherium," gives a description, evidently written by Dr. Prout, of the teeth of this specimen, also a vertical view, natural size, of the posterior tooth, which was well preserved. In the same Journal, vol. III, pp. 248-250, 1847, Dr. Prout, in an article entitled "Description of a Fossil Maxillary Bone of a Palaeotherium near White River," gives a more detailed description of the fossil referred to in the preceding volume. Two figures are given, one of the entire fossil as found and one of the last molar tooth. The locality where discovered is given as "near the latitude of 43 degrees and longitude 26 degees, or approximately 150 miles south of St. [Ft.] Pierre and 60 miles east of the Black Hills."† About the same time a few specimens obtained in much the same manner as the one described by Dr. Prout were submitted to Dr. Leidy for examination. They form the subjects of short communications in the Proceedings of the Academy of Natural Sciences of Philadelphia for 1847. These articles by Dr. Prout and by Dr. Leidy, which were the first to make public mention of White River fossils, opened the way for the extensive and important researches so persistently carried on in the White River Tertiary since that time.

*Apparently the earliest authentic reference to collections made in the Black Hills proper dates from the year 1850. Professor Ward in his paper on The Cretaceous Formations of the Black Hills as Indicated by the Fossil Plants, U. S. Geological Survey, 19th Ann. Rept., 1899, p. 529, calls attention to Edgar Allan Poe's reference to "the discovery of a completely petrified forest near the head waters of the Cheyenne, or Chienne River, which has its source in the Black Hills of the Rocky chain." The works of the late Edgar Allan Poe, with notices of his life and genius, by N. P. Willis, J. R. Lowell and R. W. Griswold; in two volumes; vol. I, Tales, New York, 1850, p. 139.

†This inaccuracy of location is doubtless due to the general lack of knowledge at that time of the geography of the Northwest.



SKETCH MAP, Showing Routes of Early Exploring Expeditions to the Black Hills Region.

In 1849 Dr. John Evans, under the direction of Dr. David Dale Owen, United States geologist, led the first expedition into the White River bad lands for the purpose of scientific observation. Dr. Evans at this time secured an excellent collection of Tertiary mammalian and chelonian remains and also collected many Cretaceous fossil in neighboring localities, particularly along Sage creek.*

The report of this expedition, which includes our first authentic description of the physical features of these now celebrated "bad lands" is given in Dr. Owen's final report of the Geological Survey of Wisconsin, Iowa and Minnesota, published in 1852. A map, reproduced in Plate III, which is the first detailed mapping of any part of the Black Hills region, also descriptions and many plates of the fossils are given in the report, the vertebrate fossils being described by Dr. Joseph Leidy, the invertebrate fossils by Dr. Owen.

In 1850 Mr. Thaddeus A. Culbertson visited the White River bad lands under the auspices of the Smithsonian Institution and made an interesting collection. This collection, together with material previously obtained, formed the basis of a paper by Dr. Leidy, published in 1852 in the Smithsonian Contributions to Knowledge, under the title of "The Ancient Fauna of Nebraska."

In 1853 Dr. Evans again made extensive collections of Tertiary fossils in the White River beds and also of Cretaceous fossils from the now well-known Sage creek locality. The vertebrates were described by Dr. Leidy in the Proceedings of the Academy of Natural Sciences of Philadelphia. Drs. Evans and Shumard made a study of the invertebrates and published their results in the Proceedings of the Academy of Sciences of St. Louis.

In the same year, 1853, Dr. F. V. Hayden and Mr. F. B. Meek, who with Dr. Leidy, already mentioned, made up

*This Sage creek, which is a southern branch of the South Fork of the Cheyenne river, is east of the Black Hills, wholly within South Dakota, which at the time of Dr. Evans' visit was a part of Nebraska territory. It should not be confused with another tributary of the South Fork of the Cheyenne, known as Upper Sage creek, formerly called Hat creek, lying south-southwest of the Hills in Wyoming.

a trio of scientists to whom especial credit is due for their work in developing the earlier knowledge of the geology and paleontology of the Black Hills region, were employed by Professor James Hall, state geologist of New York, to visit the White River bad lands for the purpose of making a collection of fossils. Their collection of mammalian remains, which was a particularly important one, was submitted to Dr. Leidy for study. The invertebrate Cretaceous forms, which were of no less importance, were studied by Professor Hall and Mr. Meek and furnished a memoir published by the Boston Academy of Science, in which was a section prepared by Mr. Meek, showing for the first time the order of succession of the different beds of the Cretaceous in the Upper Missouri region.

Dr. Hayden, in company with parties of the American Fur Company, spent the years 1854-55 in the Upper Missouri country. On March 9, 1855, he ascended Bear Butte and during the months of May and June of the same year he devoted thirty days to a study of the White River bad lands. The collection secured at this time was equally divided, one part being purchased by the Academy of Sciences of St. Louis and the other part by the Academy of Natural Sciences of Philadelphia.

In 1855 a military force, under command of General W. S. Harney, passed through a considerable part of the Bad Lands along the old trail from Fort Laramie to Fort Pierre. Lieutenant Warren, topographical engineer to the expedition made a report of this exploration, in which is given much of interest concerning the geography, topography, meteorology, etc., of the country passed through. The report is accompanied by a paper written by Dr. Hayden, who gives an account of his work in the Bad Lands a few months previous to the military expedition.

Two years later, in 1857, Lieutenant Warren accompanied by Dr. Hayden as geologist, conducted an expedition almost around the outskirts of the Black Hills. The first reliable geological information concerning the Hills proper was obtained at this time. The party consisting of twenty-two men set out from Fort Laramie September 4th and pro-

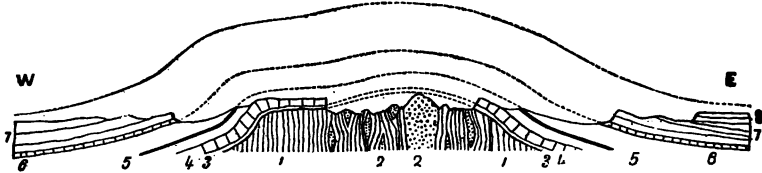


FIGURE 1. Ideal Cross-section of the Black Hills, according to Prof. Newton.

- | | |
|--------------------------------|---------------------------------------|
| 1. Archean slates and schists. | 5. Red Beds, with included limestone. |
| 2. Granite. | 6. Jura. |
| 3. Potsdam. | 7. Cretaceous. |
| 4. Carboniferous. | 8. White River Tertiary. |

Vertical scale approximately six times the horizontal.

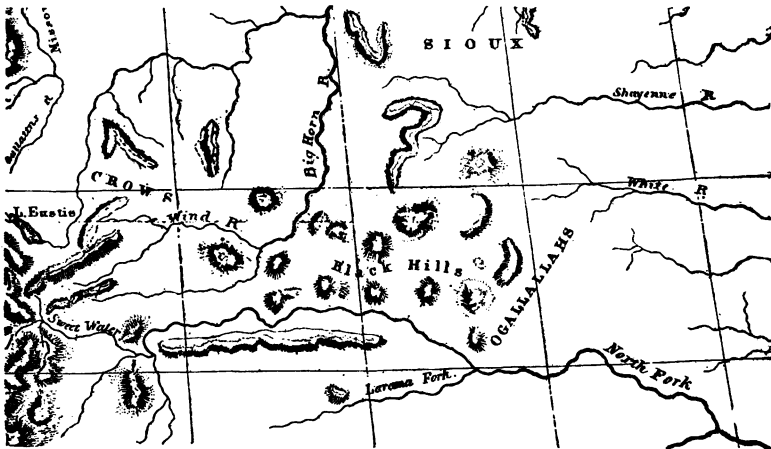


FIGURE 2. A portion of Rev. Samuel Parker's map of Oregon Territory, indicating the Black Hills as situated immediately north of the Platte. The hook-shaped ridge within the forks of the Cheyenne, corresponds more closely with the position of the Black Hills as now understood.

ceeded direct to the Black Hills by way of Raw Hide Butte, Old Woman creek, South Fork of the Cheyenne and Beaver creek. They entered the outskirts of the Hills along the East Fork of Beaver creek. Continuing northward the vicinity of Inyan Kara was reached, where after several days parleying with a large force of Indians who were herding buffaloes in the Red Water Valley, the party was compelled to return southward. They retraced their route for a considerable distance, then passed around the southern end of the Hills, following in a general way the outer rampart of the Hills eastward, then northward to Bear Butte, which point was reached September 29th. After visiting the North Fork of the Cheyenne the party went from Bear Butte southeast to Elk creek—given in the report as Bear creek—which they followed one day toward its mouth; thence to the South Fork of the Cheyenne, striking it at the mouth of Sage creek. They ascended the Cheyenne to French creek, then crossing the Bad Lands and the White river, passed out of the state between the head waters of Wounded Knee creek and White Earth creek.

Chief among the geological results of this trip was the identification of Cambrian, Carboniferous and Jurassic rocks. From this expedition dates also the careful investigation of the topography and drainage of the region, practically nothing having been known previous to this time concerning the detailed geography of the forks of the Cheyenne. The expedition was in the nature of a rather rapid reconnaissance and although Lieut. Warren had but few instruments his work proved to be unusually accurate and all subsequent maps of the region up to the Newton-Jenney survey of 1875 were based on his work.

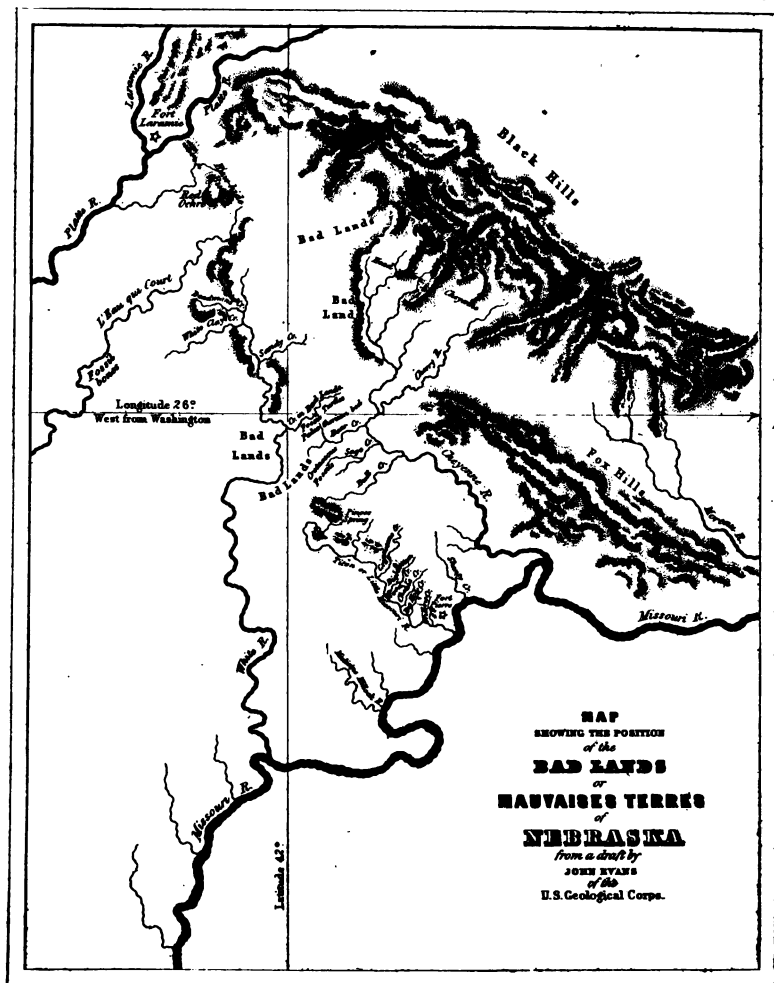
It is especially worthy of mention that the Cambrian of the Black Hills, then known as Potsdam and classified as Lower Silurian according to the usage of the time, was the first discovery of Cambrian rocks in all the Rocky Mountain region; also that Dr. Hayden obtained in the Hills at this time the first positive proof of the existence of Jurassic rocks in America.

In May of this year, 1857, the first geological map of

the northwestern part of the United States which made any pretensions at accuracy, was published by Dr. Hayden in the Proceedings of the Academy of Natural Sciences of Philadelphia. The geology of much of western South Dakota is indicated, but that part of the map representing the Black Hills proper is not colored. In June, 1858, a second edition of this map was published in the Proceedings and in this was incorporated the additional information obtained by the author during the previous year. The geology of the Black Hills proper is represented for the first time on this map.

Plate V is a reproduction of a part of the "Map of Nebraska and Dakota," published in the Journal of the Proceedings of the Academy of Natural Sciences of Philadelphia in 1869, and again in the Final Report of the U. S. Geological Survey of Nebraska, etc., in 1872. It does not therefore represent the earliest map, but it has received a wider circulation than the other and was apparently made from the same notes.

In 1859 Dr. Hayden again visited the Hills, this time as geologist to the expedition led by Capt. W. F. Reynolds. The party left Ft. Pierre June 28th. The Cheyenne was crossed at the mouth of Cherry creek and the North Fork or Belle Fourche near the mouth of Bear Butte creek. Bear Butte was ascended by several members of the party. After leaving Bear Butte the route led along the outer rim of the Hills and the party passed beyond the state in a nearly northwest direction. In his geological report of this exploration, published in 1869, Dr. Hayden summarizes the structure of the Black Hills as follows: "The nucleus or central portion is composed of red feldspathic granite, with a series of metamorphic slates and schists superimposed, and thence upon each side of the axis of elevation the various fossiliferous formations of this region follow in their order to the summits of the Cretaceous, the whole inclining against the granitoid rocks at a greater or less angle. There seems to be no unconformability in the fossiliferous rocks, from the Potsdam inclusive to the top of the Cretaceous. From these facts we



MAP OF THE WHITE RIVER BAD LANDS,

By Dr. John Evans, published in Dr. Owens' Final Report of the Geological Survey of Wisconsin, Iowa and Minnesota, 1852.--Reduced.

draw the inference that, prior to the elevation of the Black Hills, which must have occurred after the deposition of the Cretaceous rocks, all these formations presented an unbroken continuity over the whole area occupied by these mountains." These structural features, later worked out in greater detail by Professor Newton, are indicated in Figure 1, Plate II.

Plate VI is a reproduction of a portion of the geological map based on the notes of this as well as previous expeditions and shows a much better understanding of the region than is indicated in Plate VI.

In 1861, two years after the Raynolds expedition, Messrs. Meek and Hayden published in the Proceedings of the Academy of Natural Sciences of Philadelphia the first complete section of the "Tertiary" Formations of the West. The series was subdivided into the four groups: 1, Fort Union, or Great Lignitic; 2, Wind River; 3, White River; 4, Loup River.

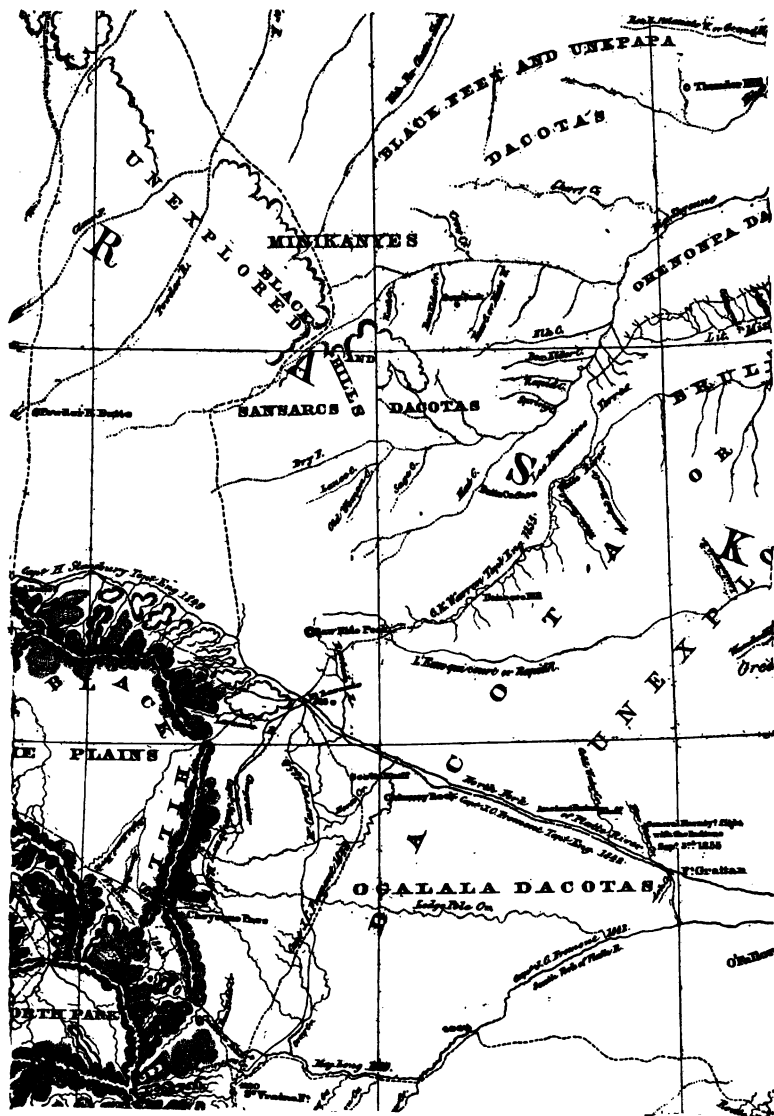
Dr. Hayden visited the Bad Lands for the last time in 1866. He went under the auspices of the Academy of Natural Sciences of Philadelphia, passing up the Niobrara river to the mouth of the Minnechadusa; thence to the head of Little White river, thus observing and collecting in portions of the basin not before visited by him. This expedition closed Dr. Hayden's field work in the Black Hills region, a region whose geological interest was brought to the attention of the scientific world largely through his researches. It is fitting therefore to relate here in Dr. Hayden's own words his idea of the importance of the region as a field for geological study. He says: "The Black Hills of Dakota will form one of the most interesting studies on this continent. There is so much regularity in the upheaval that all obscurity is removed and all the formations known in the West are revealed in zones or belts around the granitic nucleus in their fullest development. [A careful detailed topographical and geological survey of this range would be a most valuable contribution to science. In all the western country I have never seen the cretaceous, Jurassic, triassic, or red-beds, the

carboniferous and Potsdam rocks, so well exposed for study as around the Black Hills."*

In 1874 a party of 1000 men under command of Colonel G. A. Custer explored considerable portions of the Hills, including much of the difficultly accessible and hitherto unexplored mountainous area. Captain William Ludlow accompanied the expedition as chief of engineers, Professor N. H. Winchell as geologist and Mr. G. B. Grinnell as naturalist. The party left Fort Abraham Lincoln, near Bismark, North Dakota, July 1st, and traveling in a general southwesterly direction, reached the Belle Fourche a little west of the state line July 18th. From here the route led southward to Inyan Kara; thence southwest to a point on French creek, nearly due south of Harney Peak. Here detachments were sent south to the South Fork of the Cheyenne near the present site of Edgemont; east along French creek nearly to its mouth; and north to the summit of Harney Peak. The main route was then retraced for a distance of about twenty-five miles, after which the party went northeast to the headwaters of Box Elder, which creek they descended to the Red valley. They then went north to Elk creek, where they passed out upon the prairie, then north again to Bear Butte, which some of the party ascended August 15th. The party then crossed the Cheyenne and passed beyond the state line on the return journey. Professor Winchell, as a result of this expedition, published a valuable report, including numerous sections and an important geological map. It is to be noted that he was the first geologist to reach the granite area. Dr. Hayden having had opportunity to study the central portion of the Hills only from a distance. Miners and prospectors accompanying the expedition reported the finding of gold and, although not yet opened by the government for settlement, prospectors began at once to flock to the region. During this year, 1874, the South Dakota-Nebraska boundary line was surveyed by Mr. Chauncy Wiltse and Mr. E. P. Austin, his assistant, the distance measured being a little more than 224 miles.†

*Preliminary Report of the United States Geological Survey of Wyoming and Portions of Contiguous Territories, 1870. Washington, 1871, page 98.

†Wheeler, George M., Explorations and Surveys, p. 723, 1889.



A portion of Lieutenant Warren's map accompanying his "Report of Military Reconnaissances in the Dakota Country 1855," showing, approximately, the location of the Black Hills of Dakota and the Black Hills of Wyoming, as then understood.—Reduced.

The following year, 1875, is particularly prominent in the history of the Black Hills. It was during this year that a party was sent out by the Secretary of the Interior under the auspices of the United States Geographical and Geological Survey of the Rocky Mountain Region for the purpose of making a topographical survey and of obtaining information regarding the geology, the mineral deposits and other natural resources of the Hills. The professional work was performed by Walter P. Jenney, E. M., geologist in charge; Henry Newton, E. M., assistant geologist; V. T. McGillicuddy, M. D., topographer; Captain Horace B. Tuttle, A. M., astronomer; and W. F. Patrick, E. M., with a corps of eleven miners and laborers—sixteen in all.

The party, with a military escort of 400 men under command of Lieut.-Colonel R. I. Dodge, left Fort Laramie May 25th and reached the Black Hills on the East Fork of Beaver creek June 3d. From Camp Jenney on the East Fork of the Beaver the entire party entered the Hills proper, establishing the first base of operations at the stockade* on French creek.

"Here in order to expedite the work the corps was divided into two parties: (1) Mr. Jenney with the miners, assumed the work of examining the mineral deposits and prospecting the various districts for gold, and (2) Mr. Newton, Dr. McGillicuddy and Captain Tuttle were directed to undertake the more detailed and thorough topographical and geological study of the country. When the region of the southern part of the Hills had been worked up as completely as was practicable the entire expedition moved northward and established a second camp on Rapid creek below the forks, from which the region on each side was in a similar manner explored; a third camp was made on Bear Butte creek near Terry Peak, and a fourth on Inyan Kara creek, about ten miles southeast of Inyan Kara. From this last point the Bear Lodge range was examined by Mr.

*The stockade was a strong enclosure situated about three miles below the present site of Custer. It was erected in January, 1875 as a protection from hostile Indians by the members of the first expedition to enter the Hills for the purpose of settlement.

Jenney's party, while the other party descended the Belle Fourche to the mouth of Bear Butte creek, where all portions of the expedition again met. The main body of the escort then skirted the Hills on the east side to Rapid creek, while Mr. Jenney's party crossed southeastward outside of the foot hills to the mouth of Rapid creek, and the topographical party descended the Belle Fourche and ascended the South Fork of the Cheyenne to the mouth of Rapid creek, where all parts of the expedition met September 22, preparatory to the homeward march. * * * * From the mouth of the Rapid the surveying party ascended the Cheyenne river to the mouth of Burntwood creek, and then, crossing eastward to the White river, joined the main body of the military escort, which had crossed through the Bad Lands from near Spring creek. Thence following up the White river, via. the Indian agencies of Spotted Tail and Red Cloud, the expedition returned by the agency road to Fort Laramie."*

The work of the party, although limited to a single season, was carefully done and the accumulation of facts was particularly satisfactory. Prof. Jenney's preliminary report on the mineral and other resources, in which much of immediate interest centered, was published in 1876. It cleared away all lingering doubts as to the presence of gold in the Black Hills,† a considerable part of the report dealing especially with this subject. It also contains a description of various mining districts in the Hills and a discussion of the climate, water supply, soil, wild fruits, grazing and timber. The final report of the expedition, delayed at first because of the lack of appropriation and again on account of the death of Prof. Newton, which occurred at Deadwood, August 5, 1877, was published in 1880, Mr. G. K. Gilbert ably editing Prof. Newton's unfinished manuscript. Prof. Newton showed

*Report on the Geology and Resources of the Black Hills of Dakota, with atlas, by Henry Newton, E. M., and Walter P. Jenney, E. M., 1880, pp. 34-37.

†Prof. Jenney's first announcement of the finding of gold dates really from June 17, 1875, at which time he sent a message from "Camp on French creek, near Harney Peak," to the commissioner of Indian affairs at Washington, announcing that he had found gold on the north bend of Castle creek, and southward to French creek.



Portion of Dr. Hayden's "Map of Nebraska and Dakota," 1869 and 1872. Figures and dotted contact lines not in original. — Reduced.

a clear grasp of the geological problems incident to the region and discussed them in a comprehensive manner. His report is a geological classic on the Black Hills region and is a fitting monument to his memory.

In addition to the papers by Prof. Newton and Prof. Jenney four other papers were presented in the final report. Mr. Tuttle reported on the astronomical and barometric work; Professor Asa Gray on the collection of plants; Mr. John H. Caswell on the microscopic petrography and Professor R. P. Whitfield on the paleontology. The collection of fossils is said to have contributed a larger amount of new material than that gathered by any previous single expedition to the west. Among the important results of Mr. Caswell's work was the accurate determination of various rock species among the later igneous intrusions of the Northern Hills. It is of interest to note that he announced the discovery of phonolite at Black Butte, this being the first discovery of phonolite in America.

An atlas of three maps accompanies the report. Of these the topographical map and the geological map served as the basis for all later field work until the beginning of the more detailed survey now being carried on under the direction of the United States Geological Survey. The geological map of that portion of the area lying in South Dakota is reproduced with slight revision, in Plate VII. The third map, a birds-eye view of the Hills, reproduced in Plate VIII, shows the general relief of the region and indicates in a beautiful manner the topographical relation which the Hills bear to the surrounding plain. In addition to the reports by the members of the scientific staff, Lieut.-Colonel Dodge published in 1876 an interesting and helpful book descriptive of the region.

In 1877 Capt. W. S. Stanton, with a party of forty-one men, made important explorations into the Hills. Capt. Stanton, who had charge of the party and superintended the observations for time, latitude and magnetic declination was unaccompanied by a geologist, but had as members of the party a topographer and draftsman and a photographer, besides chain and rod men and a military escort.

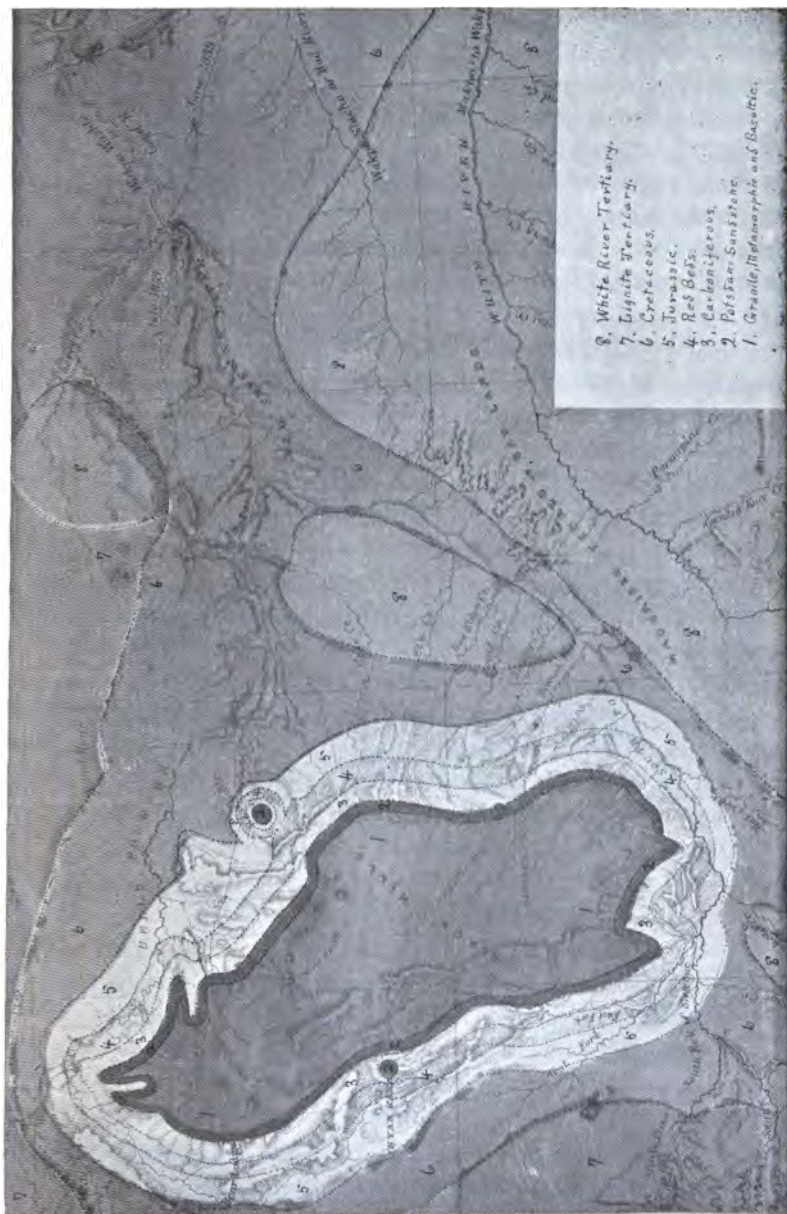
The party, leaving Fort Laramie August 1st, and enter-

ing the Hills by way of Raw Hide Butte, Hat creek, [now called Upper Sage creek?] Old Woman creek, Beaver creek and Camp Jenney, reached Deadwood, August 11th. They remained at Deadwood six days, making observations for latitude and longitude, after which the journey was continued northwest to Spearfish, thence west and southwest up the valleys of the Red Water and the Belle Fourche to Fort McKinney. This route from Deadwood was at that time the usual line of travel from the Black Hills to the Big Horn mountains, but so far as concerns that portion of the Belle Fourche along which the reconnaissance led little accurate information was known at that time.

Later in the season the party again entered the Hills from Fort Laramie. They left Fort Laramie, September 28th, for Fort Robinson, from which place they went nearly due north along the old Sidney-Deadwood stage and mail route to Rapid City, where they entered the Red valley, thence to Deadwood, October 11th, by way of Crook City. The route then led southward through Custer, where a stop was made for special observations; thence south-southwest to Hat creek; thence southeast to Fort Robinson, which place was reached October 25th. During these explorations observations were made as to latitude, longitude, altitudes, distances, comparative advantages of routes, grazing and agricultural lands. The earlier route taken by the party into the Hills was the old mail and stage route from Cheyenne to Deadwood. This had two branches from Hat creek. The eastern branch was the early stage route, but later the western branch was used instead. Captain Stanton's party first entered the Hills by way of the western branch, but later one of their routes led outward along the eastern branch.

During this year, 1877, the southern part of the Dakota-Wyoming boundary line was surveyed by Mr. Rollin B. Reeves and Mr. Horace P. Tuttle, his assistant, the distance measured being a little more than 138 miles.

Following the Newton-Jenney survey little additional information was gained so far as concerns the general geology of the Hills until the year 1888, when two publica-



A portion of Dr. Hayden's "Map of the Yellowstone and Missouri Rivers and their Tributaries," published in 1869. Figures and dotted lines not in the original.—Reduced.

tions of importance were issued. The first of these was by Professor W. O. Crosby, on the "Geology of the Black Hills of Dakota," and was published in the Proceedings of the Boston Society of Natural History. Among the principle features discussed in this paper the following may be mentioned: the geological history of the region, the origin of the granite, the presence and metamorphism of the pre-cambrian conglomerate, the nature of the igneous intrusions of the Northern Hills, some of which were shown to be true laccolites, the formation of the contact ore deposits and the cause of the deposit of gravel and boulders, which cover the prairie for many miles beyond the limits of the Hills.

The second paper, published in 1888, was a preliminary report on the geology and mineral resources of the Hills, by Dr. Franklin R. Carpenter, then dean of the State School of Mines. The conclusions reached by the author concerning the general geology of the region are much the same as those given by previous writers. The discovery of prominent pre-Cambrian conglomerates and of pre-Cambrian igneous rocks provisionally classed as diorites, is announced in the paper. Under the head of Mineral Resources the author gives a general review of the mineral industry as existing in the Hills at the time and discusses at considerable length the occurrence of gold and tin. A copy of Newton's geological map modified to show the results of later study is also given in the report. Plate VIII is a reproduction of this map as given by Mr. Persifor Frazer in his "Notes on the Northern Black Hills of South Dakota," published in the Transactions of the American Institute of Mining Engineers in 1897.

During the same year, 1888, Professor Crosby published in the Technology Quarterly a short paper on "Quartzites and Siliceous Concretions," the paper having been suggested by observations of certain phenomena on Box Elder creek. The part of the discussion referring particularly to the Hills deals mostly with the silicification of the Cambrian quartzite.

During the summer of the following year, 1889, Professor C. R. Van Hise visited the region for the purpose of studying the older rocks and in March of the following year, 1890, published in the Bulletin of the Geological Society of Amer-

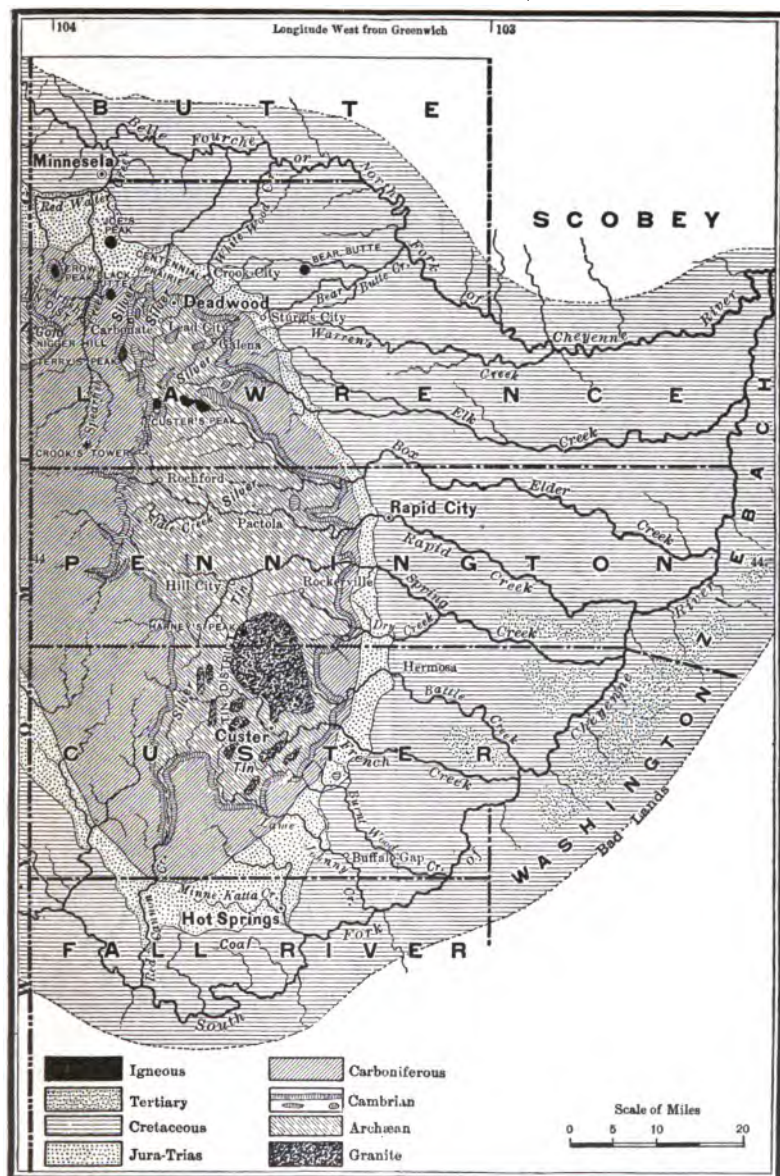
ica a paper, on "The Pre-Cambrian Rocks of the Black Hills." The more important results of his work were: the rearrangement of the areal distribution of the schists and slates as mapped by Newton; the presentation of evidence that the basic eruptives, such as hornblende schists and diorite are probably older than the eruptive granite; that the pre-Cambrian quartzites, quartz schists, mica slates, and certain of the mica gneisses are of clastic origin, while the hornblende schists are, at least in some instances, of eruptive origin; and that slaty cleavage, schistose structure and true bedding, although closely related to each other, are distinct phenomena and are all well represented in the pre-Cambrian rocks of the Hills.

The year 1892 marks the discovery of silurian strata in the Hills. During this year Mr. C. D. Wolcott, director of the United States Geological Survey, published a paper in the Bulletin of the Geological Society of America entitled "Preliminary Notes on the Discovery of a Vertebrate Fauna in Silurian (Ordovician) Strata," in which he refers in a foot note to the receipt from Dr. F. R. Carpenter of specimens of invertebrate fossils, which establish the identity of Trenton strata.

In 1893 two valuable contributions to the geological literature of the White River Bad Lands were published. The first of these by Mr. J. B. Hatcher, entitled "The Titanotherium Beds," was published in the American Naturalist and deals especially with the lithological character, areal distribution, method of deposition and triple division of the beds.

The second paper was by Dr. J. L. Wortman "On the Divisions of the White River or Lower Miocene of Dakota," and appeared in the Bulletin of the American Museum of Natural History. The paper announced the discovery of a well-defined fossiliferous horizon above the already well-known Oreodon beds. The strata containing the fossils were designated by the author as the "Protoceras layer," from the characteristic vertebrate fossil, known as Protoceras, found in them in considerable abundance.

The next publication containing a study of the general



Geological map of the Black Hills of Dakota, after the map of Professor Newton. Revised by Dr. F. R. Carpenter. Reproduced from Professor Frazer's "Notes on the Northern Black Hills of South Dakota."

geology of the Black Hills region 'was issued in 1894 as Bulletin No. 1 of the South Dakota Geological Survey, by Professor J. E. Todd, state geologist, under the title, "A Preliminary Report on the Geology of South Dakota." The report contains an excellent summary description of the geology of the Black Hills region as known up to that time and testifies to the accurate discriminating judgment of the author in discussing the results of previous work. Many new facts are also presented, the author having spent several weeks in the Hills making personal observations.

In 1898 Bulletin No. 2 of the South Dakota Geological Survey was published. Six of the scientific papers contained in this bulletin deal more or less directly with portions of the Black Hills region. The work was carried on under the direction of the state geologist, mostly during the summer of 1895, and resulted in the discovery of important facts regarding the structure and stratigraphy of the region. Among the facts brought out in these papers may be mentioned: the discovery of fossils in the lower part of the Purple Limestone; complex folding in the slates along Rapid creek; White River and Loup Fork Miocene beds overlying the Laramie north of the Black Hills in Harding, Butte and Ewing counties; an area of considerable disturbance in Harding county; and lignite beds of importance in Ewing, Harding and Martin counties.

In 1899 Mr. John D. Irving, of the Geological Department of Columbia University published an important paper entitled, "A Contribution to the Geology of the Northern Black Hills." This gives a detailed account of the geology of an area about eight miles square lying to the south of Little Crow peak and west of Central City and Englewood. The author describes the topography, the sedimentary and igneous rocks and the ore bodies of the region, announces the determination of several new types of igneous rocks, describes the structural and dynamic relations of the eruptives, indicates the causes influencing the formation of the various kinds of Black Hills intrusives and gives a geological map showing the areal distribution of the rocks studied. The ore bodies are described with reference to their method

of formation and their present relations in the several mining localities of the area.

In addition to the papers already mentioned, all of which deal more or less fully with the general geology of the Black Hills region numerous other publications have aided greatly in bringing about an accurate understanding of the geology. Owing to the fact that most of these papers are, in the main, restricted to some phase of economic geology or to particular subjects of a mineralogical, petrographical or paleontological character no effort is made here to review them in detail. In the bibliography published as the second paper of this bulletin, the general nature of the contents of each paper has been indicated. The first three classes of the publications above mentioned are closely related and aside from indicating many interesting geological features of the region have directed careful attention to its valuable mineral resources. Concerning these mineral resources it need only be said that the knowledge of their varied nature has become widespread and the financial interests permeating every part of the region and assisting in its development is unmistakable evidence of their economic importance.

In recounting the work carried on in the White River bad lands the various earlier expeditions to the region have been mentioned in consecutive order with some reference to the special results of each expedition. Since Dr. Hayden's last visit few field seasons have gone by without one or more collecting parties entering the basin for the purpose of obtaining specimens from its well-filled beds. The detailed results of all of this work, which in the main is of a highly special nature, cannot be dwelt upon here. It must suffice to mention some of the institutions represented and the years in which the visits were made. Professor Marsh visited the region for the first time in 1868. Since then Yale University, through the instrumentality of Professor Marsh, has had collecting parties in the field during portions of thirteen different seasons, as follows: 1870, 1871, 1873, 1874, 1886, 1887, 1888, 1889, 1890, 1894, 1895, 1897, 1898.* The earlier parties were made up of instructors and students

*A portion of the time indicated was spent in northwestern Nebraska.

from the university. Later the parties included only local collectors. Princeton University also early took an interest in the region, the first party, under the direction of Professor W. B. Scott, entering the Bad Lands in 1882. Collecting parties were again sent out in 1890, 1893 and 1894, the party of 1890 being as before under the personal direction of Professor Scott, that of 1894 under the direction of Mr. Hatcher, while the collections of 1893 were directed by both Professor Scott and Mr. Hatcher. The American Museum of Natural History was represented by parties under the direction of Dr. J. L. Wortman during the season of 1892 and 1894 and the Field Columbian Museum in 1898 by a party under the direction of Professor O. C. Farrington. Other universities and museums have occasionally had representatives in the field and local collectors have supplied specimens to many institutions, both in America and in Europe. The result is that to the White River bad lands some of our best equipped museums owe many of their finest specimens of fossil mammalian remains and our scientists one of the most fruitful sources of paleontologic interest.

Reference has already been made to the surveys and explorations carried on in the Black Hills region under the direction of various government organizations before the establishment in 1879 of the present United States Geological Survey. Mention of the work of this latter organization has been purposely omitted in the foregoing pages although the consecutive order of investigation, as followed in the major portion of this paper, might seem to demand its earlier presentation. I have reserved mention of this work until the last, partly because of its present continuation, partly because of its more or less connected nature, but particularly because of the fact that the very character of that work is calculated to arouse new interest in the geology of the Hills and bids fair to mark a new period in the investigation of the region.

The U. S. Geological Survey began work in the Black Hills region in the year 1890, at which time the initial astronomical point on which the triangulation of the region depends was established in the court house yard in Rapid City, by Mr. S. S. Gannett, assisted by Mr. A. F. Dunnington, the

object being to prepare a topographic map of the region suitable for use in subsequent detailed geologic mapping. During the field season of 1891 Mr. C. H. Fitch selected a base line in the valley of the Box Elder creek about four miles northeast of Rapid City, of which he made a preliminary measurement. Topographic work was carried on in the vicinity of Rapid City and Deadwood, by Messrs. R. A. Farmer and C. H. Fitch, the Rapid quadrangle being surveyed as well as portions of the Deadwood and Hermosa quadrangles. During the year 1893 Mr. E. M. Douglas extended the system of triangulation, previously begun by Mr. W. S. Post, over much of the region, locating eighteen stations and carefully remeasuring the base line previously established by Mr. Fitch. In the same season the Harney Peak and the Oelrichs quadrangles were surveyed, Mr. R. A. Farmer surveying most of the Harney Peak quadrangle, and Mr. F. M. Bannon surveying the Oelrichs quadrangle, and the unfinished portion of the Harney Peak quadrangle.*

In 1896 the U. S. government incorporated a considerable portion of the wooded area of the Black Hills region in the Black Hills Forest Reserve, since which time the Geological Survey has again engaged in the work of mapping the region, making some revisions in earlier work and carrying the survey into new areas. As a result of this and previous work six topographic sheets have been issued as follows:†

Name of Sheet.	Scale.	Contour interval	Triangulation by	Topography by
Rapid.....	Two miles to the inch.	50 feet	W. S. Post.	R. A. Farmer.
Hermosa	" " " "	100 "	E. M. Douglas	R. A. Farmer.
Deadwood.....	" " " "	100 "	E. M. Douglas	C. H. Fitch and R. A. Farmer.
Oelrichs.....	" " " "	50 "	E. M. Douglas	T. M. Bannon.
Harney Peak.....	" " " "	100 "	E. M. Douglas	R. A. Farmer and T. M. Bannon.
Sundance.....	" " " "	50 "	W. S. Post.	H. S. Wallace.

*A quadrangle, as defined by the United States Geological Survey is bounded by parallels and meridians and on the scale used in the Black Hills contains one-quarter of a square degree, or approximately 1000 square miles. The published topographic map of the quadrangle is known as a topographic sheet.

†These sheets may be procured by anyone for five cents each by addressing The Director, U. S. Geological Survey, Washington, D. C.

Thus the United States Geological Survey, having largely removed one of the most serious obstacles in the way of producing an adequate geological survey of the region, in 1898 entered upon a thorough investigation of its geology. Since that time all of the quadrangles have been wholly or partially studied, the results of which will, without doubt, prove an important factor in the future development of the Black Hills region.

In connection with this work three papers of particular interest have already appeared. One by Mr. Henry S. Graves on the "Black Hills Forest Reserve,"* another by Professor Lester F. Ward on "The Cretaceous Formations of the Black Hills as Indicated by the Fossil Plants,"† and a third by Mr. N. H. Darton on the "Jurassic Formations of the Black Hills of South Dakota."‡

Mr. Graves defines the limits of the reserve and describes the topography of the region. He indicates the lands suitable for agricultural, grazing and mining purposes, as well as the character, distribution, condition and yield of the forest covered areas, suggests methods of management and gives a detailed description of the forest as developed along the various streams of the Hills.

Professor Ward gives a history of our knowledge of the Cretaceous of the Hills, indicates the lower Cretaceous age of a considerable series of strata below the Dakota sandstone, describes the Cretaceous flora, particular attention being given to the Cycads which occur extensively developed in the region and gives in detail the geology of the Minnekahta, the Black Hawk and the Hay Creek regions. Professor Jenney contributes the field observations in the Hay Creek coal field, Professor Fontaine the notes on the lower Cretaceous plants from the same field and Dr. Knowlton on the

*U. S. Geol. Survey, 19th Ann. Rept., part V, pp. 67-167, pls. XIX-XXXVI.

†U. S. Geol. Survey, 19th Ann. Rept., part II, pp. 527-946, pls. LIII-CLXXII, figs 117-122.

‡Geol. Soc. Amer., Bull., vol. 10, pp. 383-396, pls. 42-44.

fossil wood, genus *Araucarioxylon*, from the cycad bed two miles southwest of Minnekahta station.

Mr. Darton gives a general discussion of the Black Hills Jurassic as now understood, points out the uncertainty of the Jurassic-Cretaceous contact horizon, gives the classification, composition, and nomenclature of the Triassic, Jurassic and Lower Cretaceous (or Jurassic?) formations, describes the formations in detail as developed in various localities and outlines the history of Jurassic deposition in the Black Hills region.

A BIBLIOGRAPHY

Of Contributions to the Geology and Geography of the Black Hills Region.*

BY CLEOPHAS C. O'HARRA.

1846.

1. [PROUT, HIRAM A.] Gigantic Palaeotherium.

Am. Jour. Sci., vol. II, pp. 288-289.

This is published under the head of Miscellaneous Intelligence and is the first reference to organic remains from the White River bad lands of South Dakota. The specimen, which is a portion of the lower jaw, was obtained by Dr. Prout, of St. Louis, from individuals in the employ of the American Fur Company. A few measurements of the posterior tooth are given.

1847.

2. PROUT, HIRAM A. A Description of a Fossil Maxillary Bone of a Palaeotherium from near White River.

Am. Jour. Sci., vol. III, pp. 248-250. Communication dated St. Louis, December 10, 1846.

The fossil is described as having been discovered near latitude 48° north and longitude 26° west, or approximately 150 miles south of St. [Ft.] Pierre, and 60 miles east of the Black Hills. The specimen is a fragment of the inferior maxillary of the left side, consisting of the posterior part of the bone, together with the last three molar teeth, the last one of which

*This bibliography is not complete. Lack of opportunity has prevented the thorough examination of all of the geological literature; therefore a number of papers are necessarily omitted. This will perhaps be most noticeable to those interested in vertebrate paleontology. Frequent requests for a list of publications on the geology of the region have led to the publication of the bibliography as here presented. With the exception of Nos. 123, 132, 133, 145, 146, only the titles of papers are given which I have personally examined. In the case of the exceptions the titles, summaries of contents, etc., have been taken from the U. S. Geological Survey bibliographies by Mr. Fred B. Weeks, the number of the bulletin being indicated.

is quite well preserved. One figure of the entire fossil one-fourth natural size, and one figure of the last molar tooth four-fifths natural size, are given.

1852.

3. LEIDY, JOSEPH. Description of the Remains of Extinct Mammalia and Chelonia from Nebraska Territory, Collected During the Geological Survey under the Direction of Dr. David Dale Owen.

Report of a Geological Survey of Wisconsin, Iowa and Minnesota, and Incidentally a portion of Nebraska Territory, by David Dale Owen, United States Geologist, Philadelphia, 1852, pp. 533-572, tables IX-XV, map.

The author considers the strata as being of Eocene age and describes the following forms: *Oreodon Culbertsoni*, *O. gracilis*, *Palaeotherium? proutii*, *Rhinoceros occidentalis*, *R. nebrascensis*, *Archaeotherium mortoni*, *Eucrotaphus auritus*, *Machairodus primaevus*, *Testudo nebrascensis*, *T. oweni*, *T. culbertsonii*, *T. hemispherica*. A synopsis of the following forms obtained from the same region is also given: *Poebrotherium wilsoni*, *Agriochoerus antiquus*, *Archaeotherium robustum*, *Architherium bairdii*, *Testudo lata*.

4. OWEN, DAVID DALE. Incidental Observations on the Missouri River, and on the Mauvaises Terres (Bad Lands).

Report of a Geological Survey of Wisconsin, Iowa and Minnesota, and Incidentally a portion of Nebraska Territory, by David Dale Owen, United States Geologist, Philadelphia, 1852. pp. 194-206, one fig., one map.

This paper contains the report of Dr. John Evans, who visited the White River bad lands during the summer of 1849. Mentions the finding of numerous and well-preserved fossils on Sage creek. Describes briefly the peculiar topographic features of the bad lands and the general nature of the fossils found. Considers the beds as of Eocene Tertiary age, and as having been deposited in fresh water. A view of the bad lands and a columnar section are given. The map by Dr. Evans is the first detailed map of any part of the Black Hills region.

5. ——— Description of New and Imperfectly Known Genera and Species of Organic Remains, Collected During the Geological Survey of Wisconsin, Iowa and Minnesota.

Report of a Geological Survey of Wisconsin, Iowa and Minnesota, and Incidentally a Portion of Nebraska Territory, by David Dale Owen, United States Geologist, Philadelphia, 1852. pp. 573-587, tables I-VIII.

Describes and figures the following named fossils from Sage creek,

near the Bad Lands: *Baculites compressus*? B. (undet.) *Scaphites nodosus*, *Inoceramus nebrascensis*.

1854.

6. LEIDY, JOSEPH. The Ancient Fauna of Nebraska, or a Description of Remains of Extinct Mammalia and Chelonia from the Mauvaises Terres of Nebraska.

Smith. Contrib. Knowl., vol. VI., pp. 1854.

Paper based on collections submitted by the Smithsonian Institution. Dr. David Dale Owen, Dr. Hiram A. Prout and Professor O'Loughland. The fossils described were all found in the White River bad lands, South Dakota, being at that time included within the Territory of Nebraska. Gives a resume of our knowledge of Tertiary mammals of North America, includes a bibliography of the literature and reviews the earlier explorations in the Bad Lands. Describes fifteen species of Mammalia, five species of Chelonia, gives twenty-four excellent plates of several figures each and a map of the Bad Lands by Dr. John Evans.

1856.

7. HAYDEN, FERDINAND V. [Sketch of the Geology and Physical Features of the Region of the Upper Missouri.]

Explorations in the Dakota country in the year 1855, by Lieutenant G. K. Warren, Topographical Engineer of the "Sioux Expedition," 35th Cong., 1st Sess., Sen. Ex. Doc. No. 76, pp. 66-76, Washington.

Includes an account of the author's visit to the White River bad lands in May and June, 1855, at which time a good collection of fossils was obtained. Mentions the fact of his ascending Bear butte on March 9th, preceeding the visit to the Bad Lands.

8. WARREN, LIEUTENANT G. K. Report of the "Sioux Expedition" of Explorations in the Dakota country, 1855.

34th Cong., 1st Sess., Sen. Ex. Doc., No. 76, pp. 1-62, 2 figs., maps, Washington, 1856.

Gives a general account of the exploration, including brief descriptions of the Black Hills and the Bad Lands and the various rivers draining the region. Appendix A, accompanying the report, gives a detailed journal of the routes, and Appendix D, daily observations of weather conditions. Three maps accompany the report.

1861.

9. HAYDEN, FERDINAND V. On the Geology and Natural History of the Upper Missouri.

Am. Phil. Soc., Trans., vol. XII., pt. I, pp. 1-230, map.

Contains the substance of a later official report made by Dr. Hayden, surgeon and geologist of the Expedition to the Upper Missouri

and Yellowstone, under the command of Lieutenant Warren. Gives an account of the work of previous explorers. Much of the paper is taken up with the geology in the immediate vicinity of the Black Hills, this being the first detailed account of the geology of the region. Numerous columnar sections are given, and certain correlations are made. An outline reduction of the map of Kansas, Nebraska and Dakota, showing topography by Warren and geology by Hayden, is also given.

This paper, with little change, was published by the United States government in 1869, under the title, "Geological Report of the Exploration of the Yellowstone and Missouri Rivers."

10. MEEK, F. B., and HAYDEN, F. V. Descriptions of New Lower Silurian (Primordial), Jurassic, Cretaceous and Tertiary Fossils Collected in Nebraska by the Exploring Expedition under the command of Captain W. F. Reynolds, U. S. Topographical Engineer; with some Remarks on the Rocks from which they were obtained.

Phil. Acad. Nat. Sci., Proc., pp. 415-447.

Refers frequently to fossils from Black Hills localities.

1864.

11. MEEK, F. B. and HAYDEN, F. V. Paleontology of the Upper Missouri.

Am. Phil. Soc., Trans., May; pp. 1-135, pls. I-XX, many figures.

This is the first part of a work containing descriptions and illustrations of the invertebrate fossil remains collected by Dr. Hayden and others while connected with the exploring expeditions under the command of Lieutenant G. K. Warren. Preliminary notices of most of the species described had been previously published from time to time under the joint names of the authors, in the Proceedings of the Philadelphia Academy of Science. These were later largely rewritten and extended by the senior author, Mr. Meek. Frequent reference is made to fossils collected in the Black Hills region.

1868.

12. RAYNOLDS, CAPT. W. F. Report on the Explorations of the Yellowstone River.

Rept. Sec. War, 40th Cong., 1st Sess., Ex. Doc., No. 77, 174 pp., map.

Gives a journal account of the explorations and makes various references to the Black Hills region, the observations having been made while skirting the Hills on the north.

1869.

13. HAYDEN, F. V. Geological Report of the Exploration

of the Yellowstone and Missouri Rivers, under the Direction of Captain W. F. Reynolds in 1859-60.

8vo, 174 pp., map, Washington.

This paper, with little change was published in the Transactions of the American Philosophical Society, vol. XII, pt. I, pp. 1-290. See 1861.

14. ——— On the Geology of the Tertiary Formations of Dakota and Nebraska.

Phil. Acad. Nat. Sci., Journ., vol. VII, pp. 9-21., map.

Reviews the Tertiary history of the West. Describes the areas covered by Tertiary lakes, gives a general section of the Tertiary rocks of Nebraska—including South Dakota, a vertical section showing the order of superposition of the different beds of the Tertiary basin of White and Niobrara rivers. Discusses the origin of the sediments and method of accumulation of the fossils and gives a catalogue of the animals thus far discovered in the White River basin, showing the vertical range of the species. The geological map accompanying this paper shows an error in the coloring by a transfer of the colors used for the granite and metamorphic to the Potsdam sandstone and *vice versa*.

15. LEIDY, JOSEPH. The Extinct Mammalian Fauna of Dakota and Nebraska, Including an Account of Some Allied Forms from other Localities, together with a Synopsis of the Mammalian remains of North America.

Phil. Acad. Nat. Sci., Jour., vol. VII, pp. 28-472, pls. I-XXIX.

Gives a brief account of the early expeditions to the White River bad lands. Describes the manner and the degree of petrification of the bones. Describes and figures seventy-seven species of mammals, most of which are from the White River beds and believed to be of Miocene age.

1871.

16. HAYDEN, FERDINAND V. Geology of the Missouri Valley.

Prelim. Rept. U. S. Surv. of Wyoming and Portions of Contiguous Territories, 1871, pp. 85-188., map.

Gives a general section of the Cretaceous rocks of the Northwest, also a general section of the Tertiary rocks of Nebraska, including what is now South Dakota. Indicates the value of a careful topographical and geological survey of the Black Hills region and gives an interesting description of the White River bad lands with a figure of the same. In

the geological map accompanying his paper the error in coloring referred to in No. 14, is also observed.

17. LEIDY, JOSEPH. Report on the Vertebrate Fossils of the Tertiary Formations of the West.

Prelim. Rept. U. S. Geol. Surv. of Wyoming and Portions of Contiguous Territories, 1871, pp. 840-370.

Brief notice of vertebrate fossils collected in the Tertiary deposits of the West, many of which were obtained in the White River bad lands. A fuller account of most of these is given by the author in "The Extinct Mammalian Fauna of Dakota and Nebraska," published in 1869.

18. ——— Remarks on Fossil Vertebrates from Wyoming.

Phil. Acad. Nat. Sci., Proc., Aug. 8, 1871.,

Contrasts the Wyoming Tertiary fauna with the later fauna of the bad lands of the White River and of the Niobrara of Nebraska. States that "among the large number of fossils from these two localities, rich in evidence of mammalian life, there occur the remains of a single species of turtle in each and none of crocodiles or other reptiles."

19. NEWBERRY, JOHN S. The Ancient Lakes of Western America; Their Deposits and Drainage.

Am. Nat., vol. IV, pp. 641-660.

An interesting discussion of the lakes, particularly those of Tertiary age, but makes no specific mention of the White River bad lands. Published also in the Preliminary Report, U. S. Geological Survey of Wyoming and portions of Contiguous Territories, 1871, pp. 329-339.

1873.

20. LEIDY, JOSEPH. Contributions to the Extinct Vertebrate Fauna of the Western Territories.

U. S. Geol. Surv. of the Terr., Rept., vol. I, pt. I, 358 pp.; pl. I-XXXVII.

Refers frequently to the fossils from the White River Tertiary by way of comparison.

1873.

21. GRINNELL, GEORGE B. Paleontological Report.

Eng. Dept., U. S. Army, Report of a Reconnaissance of the Black Hills of Dakota, made in the summer of 1874, 8vo, pp. 75-78.

Gives names of fossils and localities where collected.

22. HAYDEN, FERDINAND V. Catalogue of the Collections in Geology and Natural History Obtained under Command of Lieutenant G. K. Warren.

U. S. Army, Eng. Dept., Rept. to Lieut. G. K. Warren in his Report to Captain A. A. Humphreys, pp. 61-125.

Discusses the results of geological study in Nebraska and Dakota,

by Dr. Hayden, chiefly while with Lieutenant Warren. Gives various columnar sections and tables of collections. Much of the paper refers to the Black Hills region.

23. LUDLOW, WILLIAM. Engineers' Report.

Eng. Dept., U. S. Army, Report of a Reconnaissance of the Black Hills of Dakota, made in the summer of 1874, 8vo. pp. 1-19., map.

Gives an account of the organization of the party and a general description of the country passed through. Tables of observations for time and latitude accompany the report.

24. MARSH, OTHNIEL C. Notice of New Tertiary Mammals.

Am Jour. Sci., 8d ser., vol. IX, pp. 239-250.

Describes *Laopithecus robustus* from the *Oreodon* beds of the White River Miocene.

25. ——— Ancient Lake Basins of the Rocky Mountain Region.

Am. Jour. Sci., 8d ser., vol. IX, pp. 49-52.

Describes the Eocene, Miocene and Pliocene lake basins including the White River basin near the Black Hills.

26. WARREN, LIEUT. G. K. Preliminary Report of Explorations in Nebraska and Dakota in the years 1855-56-57.

U. S. Army, Eng. Dept., Rept. to Capt. A. A. Humphreys, 8vo., 125 pp., map.

Gives an account of routes explored, the geography, character of soil and resources, climate, comparative advantages of different routes, etc. Much of this has to do with the immediate vicinity of the Black Hills,

27. WHITFIELD, ROBERT P. Descriptions of New Fossils.

Eng. Dept., U. S. Army, Report of a Reconnaissance of the Black Hills of Dakota, made in the summer of 1874, 8vo. pp 103-104, pl.

Describes and figures *Obolus pectenoides* and *Terebratula helena*, also figures *Lingulepis primaeformis*.

28. Winchell, N. H. Geological Report.

Eng. Dept., U. S. Army, Report of a Reconnaissance of the Black Hills of Dakota, Made in the Summer of 1874. 8vo. pp. 21-66, map.

Gives results of the geological investigations in journalistic form without especial effort at generalization. Many sections and figures are given. Distinguishes and defines the Minnelusa sandstone, the name being derived from the Minnelusa valley, in the western part of

Hills. Determines the geological age of some of the rocks more definitely than had been possible in previous surveys. A valuable geological map accompanies the report.

1876.

29. DODGE, LIEUT. COL. RICHARD I. The Black Hills.

Sm. 8vo., 151 pp., 14 pls. New York, 1876.

Gives "a minute description of the routes, scenery, soil, climate, timber, gold, geology, zoology, etc., with an accurate map, four sectional drawings and ten plates from photographs taken on the spot." The book is a delightful narrative of the Newton-Jenney survey of 1875 and contains much information of value to those interested in the early development of the region.

30. MEEK, F. B. A Report on the Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country.

U. S. Geol. Surv. of the Terr., Rept., vol. IX, 629 pp., pl. I-XLV.

Describes and figures many Invertebrate forms collected by Dr. Hayden in the Black Hills region. Preliminary notices of most of these had previously appeared in the Proceedings of the Academy of Natural Sciences of Philadelphia.

1878.

31. MAGUIRE, H. N. The Coming Empire. A Complete and Reliable Treatise on the Black Hills, Yellowstone and Big Horn Regions.

Small 8vo., Sioux City, Iowa, 1878.

A narrative of early history. Gives reasons for supposing that gold was found in the Black Hills as early as 1849.

32. STANTON, CAPT. W. S. Annual Report Upon Explorations and Surveys in the Department of the Platte.

Ann. Rept. Chief Eng., Append. R. R., pp. 1705-1747; pl. 1-14.

An account of explorations in the Black Hills region. Gives a description of routes and includes hypsometric, astronomic and barometric measurements,

1879.

33. COPE, EDWARD D. The Relations of the Horizon of Extinct Vertebrata of Europe and America.

U. S. Geog. and Geol. Surv. of the Terr., Bull., vol. V., No. 1, pp. 33-54.

Includes comparisons and discussions of relations of the White River Tertiary to similar formations elsewhere in America and in

Europe. A diagram is given, showing the proper position, paleontologically considered, of the series of American and European strata.

1880.

34. CASWELL, JOHN H. Microscopic Petrography [of the Black Hills.]

U. S. Geog. and Geol. Surv., Report on the Geology and Resources of the Black Hills of Dakota, pp. 471-537, pls. I-II.

Gives a careful description of the quartzites, mica schists, slates, rhyolites, trachytes, and phonolites of the Black Hills. Eight figures accompanying the report show the microscopic structure of two rhyolites, two phonolites and four sanadine trachytes.

35. COPE, EDWARD D. On the Extinct Cats of America. Am. Nat., vol. XIV, pp. 888-858.

Describes *Hoplophoneus primaevus* from the White River beds and refers to others from the same locality.

36. JENNEY, WALTER P. Mineral Resources of the Black Hills of Dakota.

U. S. Geog. and Geol. Surv., Report on the Geology and Resources of the Black Hills of Dakota, pp. 225-300.

Paper largely taken up with the consideration of the value and character of the gold deposits. Gives a classification of the deposits and describes the geology and resources of the various mining districts. Concludes that there is gold enough in the Black Hills to cause a thorough settlement of the country.

37. ——— Climate and Resources [of the Black Hills.]

U. S. Geog. and Geol. Surv., Report on the Geology and Resources of the Black Hills of Dakota, pp. 301-324.

Gives a description of the climate, water supply, soil, wild fruits grazing and timber.

38. NEWTON, HENRY. Geology of the Black Hills.

U. S. Geog. and Geol. Surv., Report on the Geology and Resources of the Black Hills of Dakota, pp. 1-222, figs. 1-27, maps.

Report of Geological work done during the year 1875, the paper being edited by Mr. G. K. Gilbert on account of the death of Mr. Newton soon after the completion of the field work. The paper is a comprehensive description of the general geology of the Black Hills, including observations along the routes to and from the Hills. Gives an account of the origin and organization of the Newton-Jenney survey, also a brief sketch of previous explorations in the Upper Missouri region. Discusses the structure of the region, the probable geological history of the Hills, the age of the igneous, metamorphic and sedimentary rocks, together with their manner of formation or deposition and

the relation of the topography and drainage to the structure. Much attention is given to the description of the various formations including their thickness, general character and areal distribution. Numerous excellent structures and columnar sections are given. A large atlas containing a colored geological map, a topographic map and a bird's-eye view of the region, accompanies the complete report.

39. WHITFIELD, ROBERT P. Paleontological Report on the Fossils Collected by the United States Geological and Geographical Survey of the Black Hills.

U. S. Geol. and Geol. Surv., Report on the Geology and Resources of the Black Hills of Dakota, pp. 329-468; pls. I-XVI.

Describes and figures 117 species. Of these thirteen are from the "Potsdam group," thirty-three from the Jurassic and seventy-one from the Cretaceous. A synopsis of species from the Black Hills, noticed in other works but not described in this report, is also given.

1882.

40. COPE, EDWARD D. The Tertiary Formations of the Central Region of the United States.

Am. Nat. Mch., pp. 177-195.

Discusses the topography, structure, stratigraphy and paleontology of the various regions. Much of the information in regard to the White River area is obtained from papers written by Dr. Hayden.

41. ——— Review of the Rodentia of the Miocene Period of North America.

U. S. Geol. and Geol. Surv. of the Terr., Bull., vol. VI, pp. 361-386.

Gives a table showing the distribution of the species of the American Miocene rodentia of which eleven species are represented in the White River beds.

42. DEVEREUX, WALTER B. The Occurrence of Gold in the Potsdam Formation, Black Hills, Dakota.

Am. Inst. Min. Eng., Trans., vol. X, pp. 465-475.

States that the gold occurs as a mechanical and as a chemical constituent. Considers that the deposits, a conglomerate, are ocean sediments laid down on a beach. States that the gold may be called placer gold and the deposits fossil placers. Discusses the condition of deposition and concentration of the gold, the percentage of silver and the probable geological history of events leading up to the formation of the deposits.

43. HAYDEN, FERDINAND V. Report of the Director.

U. S. Geol. Surv., 3d Ann. Rept., pp. 42-44.

Reviews briefly the geology and geological work of the Black Hills region.

44. KING, CLARENCE. Production of the Precious Metals.

U. S. Geol. Surv., 2d Ann. Rept., pp. 337-401, pl. XLVIII-LIII.

Gives the production of gold and silver from the deep mines of Custer, Lawrence and Pennington counties, and the production of gold from the placer mines of Lawrence and Pennington counties for the year ending May 31, 1880.

1883.

45. BLAKE, WILLIAM P. Cassiterite, Spodumene and Beryl in the Black Hills, Dakota.

Am. Jour. Sci., 8d ser., vol. XXVI, p. 235.

Gives a short description of the minerals, their occurrence, and crystallization. Refers particularly to the Etta claim in the Harney Peak district.

46. COPE, EDWARD D. On the Extinct Dogs of North America.

Am. Nat., March, pp.

Mentions *Galeocynus gregarius* as abundant in South Dakota.

47. LESQUEREUX, LEO. Contributions to the Fossil Flora of the Western Territories, Part III, the Cretaceous and Tertiary Floras.

U. S. Geol. Surv. of the Terr., vol. VIII, 283 pp., pls. I-LIX.

Under the head "Description of Miocene species from specimens obtained in the 'so-called Bad Lands of Dakota,'" the author describes and figures numerous specimens obtained from Professors Denton, McBride and Winchell. In most cases the exact locality is not given.

48. WILLIAMS, ALBERT, JR. Mineral Resources of the United States.

U. S. Geol. Surv., Min. Res., 8vo., 813 pp.

References to Black Hills resources are given as follows; p. 49, coal; pp. 172-185, gold and silver; p. 528, gypsum; p. 541, salt; p. 583, mica; p. 591, graphite. Page 754 contains a table of ores and minerals of industrial importance mined or known to be present in the Black Hills.

1884.

49. BLAKE, WILLIAM P. Columbite in the Black Hills of Dakota.

Am. Jour. Sci., 3d ser., vol. XXVIII, pp. 340-341.

This is the first notice of columbite from the Black Hills. The author describes the columbite in the Harney Peak district, particularly

at the Etta and the Ingersoll mines. At the latter place a mass approximately 20x20x24 inches and one ton in weight, was found protruding from a matrix of albite and quartz.

50. SCHAEFFER, CHARLES A. A New Tantalite Locality.
Am. Jour. Sci., 3d ser., vol. XXVIII, p. 430.

Gives chemical analysis and specific gravity of tantalite from the Black Hills, associated with scorodite, leucopyrite and olivenite.

51. ——— Note on Tantalite and Other Minerals Accompanying the Tin Ore in the Black Hills.

Am. Inst. Min. Eng., Trans., vol. XIII, pp. 231-233.

Describes specimens from the Etta tin mine and gives a chemical analysis of the tantalite.

1885.

52. BLAKE, WILLIAM P. Tin Ore Veins in the Black Hills, Dakota.

Am. Inst. Min. Eng., Trans., vol. XIII, pp. 691-696.

Discusses the occurrence and associates of the Black Hills cassiterite, the structure of the Etta vein, the percentage of cassiterite in the ore, extent of the tin region and the time of origin of the tin ore and its associates.

53. ——— Tantalite and Columbite in the Black Hills of Dakota.

Am. Inst. Min. Eng., Trans., vol. XIII, pp. 696-697.

Gives observations upon the occurrence of the minerals with the tin ore. States that one mass of columbite or tantalite from the Ingersoll claim weighed approximately two thousand pounds.

54. EMMONS, SAMUEL F. Geological Sketch of the Black Hills of Dakota.

Tenth Census, vol. XIII, Precious Metals, pp. 89-94.

Reviews the geology of the Hills, much of the information being obtained from papers by Professors Newton, Jenney and Devereux. Many Black Hills mineral, their localities and associates are also given.

55. WILLIAMS, ALBERT, JR. Mineral Resources of the United States, Calendar Years 1883 and 1884.

U. S. Geol. Surv., Min. Res., 8vo., 1016 pp.

References to Black Hills resources are given as follows: pp. 812-821, gold and silver; pp. 602-613, tin; p. 812, gypsum; p. 843, salt,

pp. 909-910, mica; p. 913, asbestos; p. 980, mineral waters. The report on tin by Mr. W. P. Blake, gives an excellent account of the geology and development of the Black Hills tin districts.

1886.

56. WHITE, CHARLES A. On the Fresh Water Invertebrates of the North American Jurassic.

U. S. Geol. Surv., Bull. 29, pp. 1-24, pls. I-IV.

Gives descriptions and figures of certain specimens previously described by Meek and Hayden. Refers to these forms in a discussion of the probable physical geography of the region during the Jurassic period.

57. WILLIAMS, ALBERT, JR. Mineral Resources of the United States, Calendar Year 1885.

U. S. Geol. Surv., Min. Res., 8vo, 576 pp.

References to Black Hills resources are given as follows: pp. 200-207, gold and silver; p. 370, tin; p. 518, mica.

1887.

58. DAY, DAVID T. Mineral Resources of the United States, Calendar Year 1886.

U. S. Geol. Surv., Min. Res., 8vo., 813 pp.

References to Black Hills resources are given as follows: pp. 104-108, gold and silver; p. 140, lead; p. 214, tin; p. 548, building stone; pp. 622-623, gypsum.

59. MARSH, OTHNIEL C. Notice of New Fossil Mammals.

Am. Jour. Sci., 3d ser., vol. XXXIV, pp. 223-331.

Describes *Brontops dispar*, *Menops varians*, *Titanops elatus* and *Allops serrotinus* from the Miocene of Dakota.

1888.

60. CARPENTER, FRANKLIN R. Notes on the Geology of the Black Hills.

Dak. Sch. Mines, Prelim. Rept., pp. 1-52, map.

Gives a general description of the geology of the region. Discredits the theory that the granites are eruptive. Announces the discovery of prominent conglomerates in the pre-Cambrian rocks and mentions the presence of a dike of igneous rocks, provisionally classed as diorite, also in the pre-Cambrian. Discusses the geological history of the Hills. Considers that the Purple Limestone is a chemical precipitate. Refers to the "volcanic plugs or necks" of the Northern Hills

and suggests the apparently true laccolitic nature of some of the intrusions. A colored geological map, slightly revised from Newton's map, accompanies the paper.

61. ——— The Mineral Resources of the Black Hills, their Character, Occurrence and Extent.

Dak. Sch. Mines, Prelim. Rept., pp. 107-171.

Deals mostly with the occurrence and production of gold, silver, copper, nickel, tin, and structural materials. Classifies and describes the auriferous deposits and describes methods of treating the ore. Discusses the occurrence and association of the cassiterite and suggests methods of treatment. Numerous tests are given showing the percentage of black tin in the rock.

62. CROSBY, WILLIAM O. Quartzites and Siliceous Concretions.

Tech. Quart., May, pp. 397-407.

Paper suggested by certain phenomena observed on Box Elder creek. Notes the very variable nature of the lower beds of the "Potdam," it being calcareous, glauconitic, a normal sandstone, a conglomerate or a firm quartzite. Mentions dikes connecting the intrusive sheets. Divides the quartzites of the Black Hills into two divisions: those associated with igneous rocks and the quartzites beyond the influence of volcanic action. Discusses the probable two-fold origin of the cementing silica.

63. ——— Geology of the Black Hills of Dakota.

Bost. Soc. Nat. Hist., Proc., vol. XXIII, pp. 488-517.

Describes the rocks and discusses the structure and the history of the region. Thinks with Newton that the pre-Cambrian rocks may be divided into two groups, viz.: an older or Western series and a younger or Eastern series. Describes the conglomerate of the Eastern series, which previously had not been observed. Concludes that true eruptive granite is probably entirely wanting in the Black Hills, but that it is of the nature of segregated veins. Gives the probable relation of the cones, sheets and dikes in the Northern Hills, shows the presence of true laccolites and discusses the cause of the boulder cap surrounding the Hills.

64. DAY, DAVID T. Mineral Resources of the United States, Calendar Year 1887.

U. S. Geol. Surv., Min. Res., 8vo, 882 pp.

References to Black Hills Resources are given as follows: pp. 68-69, gold and silver; p. 110, lead; pp. 184-186, tin; p. 661, mica.

Pages 716-718 contain a table of ores and minerals of industrial importance mined or known to be present in the Hills.

1889.

65. MARSH, OTHNIEL C. Restoration of Brontops Robustus from the Miocene of America.

Am. Jour. Sci., 3d ser., vol. XXXVII, pp. 163-165, pl. VI.

Describes this as belonging to the largest group of mammals in the American Miocene, the skeleton of which was found in the White River beds in 1874. States that the Brontotheridae to which the Brontops belongs nearly equalled in size the existing elephant, that it belongs to the distinct order of perissodactyles and that it is more nearly allied to the rhinoceros than to any other living form.

66. WARD, LESTER F. The Geological Distribution of Fossil Plants.

U. S. Geol. Surv., 8th Ann. Rept., part II, pp. 669-960, pl. LXL

Refers on pp. 903-904 to collections of fossil plants from the Black Hills region.

67. WARREN, LIEUTENANT G. K. Memoir Giving a Brief Account of Each of the Exploring [erroneously printed "English,"] Expeditions [West of the Mississippi River] Since A. D. 1880.

U. S. Geog. Surv., vol. I, Geog. Rept., pp. 513-597, map.

This is a brief and excellent account of the many exploring expeditions sent out by the government previous to the year 1857. The routes of several of the Black Hills expeditions are given, also the methods employed in making observations as well as titles of publications resulting from the work done.

68. WHEELER, GEORGE M. Explorations and Surveys [West of the Mississippi River], 1857-1800.

U. S. Geog. Surv., vol. I, Geog. Rept., pp. 599-745, map.

This paper is a continuation of the memoir by Lieutenant Warren, published in the same report, and the general character of the two papers is identical.

1890.

69. CHANCE, H. M. The Resources of the Black Hills and Big Horn Country, Wyoming.

Am. Inst. Min. Eng., Trans., vol XIX, pp. 49-58.

Gives the results of an examination made in 1887-88 of the country lying between the Black Hills and the Big Horn mountains. Refers

briefly to the structure, resources and scenery of the Hills. States that the oil and coal deposits near Newcastle are in the Dakota sandstone.

70. CLARK, FRANK W. Report of Work Done in the Division of Chemistry and Physics.

U. S. Geol. Surv., Bull. No. 60, 174 pp.

Gives on pages 135-136 an analysis of Triplite from "a tin mine near Rapid City," as determined by L. G. Eakins.

71. DAY, DAVID T. Mineral Resources of the United States, Calendar Year 1888.

U. S. Geol. Surv., Min. Res., 8vo, 652 pp.

References to Black Hills resources are given as follows: pp. 36-22, gold and silver; pp. 144-156, tin.

72. HEADDEN, WILLIAM P. Columbite and Tantalite from the Black Hills.

Col. Sci. Soc., Proc., vol. III, pt. III, pp. 323-346.

Notes that all of the Black Hills columbites are rich in manganese. Gives the chemical composition and specific gravity of columbite from seventeen different Black Hills localities. Discusses the physical characters and associations of specimens from the Etta tin mines, the chief source. Gives also a description and two analyses of manganese columbite from the Advance claim, one and one-half miles south of the Etta mine.

This paper with some additions appeared in the American Journal of Science for 1891.

73. ——— Notes on the Discovery and Occurrence of Tin Ore in the Black Hills, S. D.

Col. Sci. Soc., Proc., vol. III, pt. III, pp. 347-350.

States that the earliest identification of tin from the Black Hills was in 1876 by Mr. Richard Pearce, of Denver, Colorado, who detected cassiterite as stream tin in gold dust from the Northern Hills. The second discovery was made on Elk gulch, southern section, in April, 1877. The material from the latter place was assayed by Theodore Vosburg, but the true nature of the bullion was first recognized by Mr. Fred J. Cross. Dates of various other discoveries and remarks on the general geology of the region are also given.

74. MARSH, OTHNIEL C. Notice of New Tertiary Mammals.

Am. Jour. Sci., 3d ser., vol. XXXIX, pp. 523-525.

Describes from the "Miocene Brontotherium beds" of the White

River basin: *Diploconus amplius*, *Teleodus avus*, *Colodon luxatus*, *Hypotamius depletus*, *Limnohyops laticeps*.

75. ——— Notice of Some Extinct Testudinata.

Am. Jour. Sci., 3d ser., vol. XL, pp. 177-179, pls. VII-VIII.

Describes the new species *Testudo brontops* from the Lower Miocene of South Dakota, which includes the largest American tortoises known, either living or extinct. States that some specimens observed in the field are surpassed in size only by the gigantic forms from the Pliocene of India.

76. ——— Description of New Dinosaurian Reptiles.

Am. Jour. Sci., 3d ser., vol. XXXIX, pp. 81-86.

Describes portions of the new species and genus *Barosaurus lentus* and figures a caudal vertebra from Piedmont, South Dakota.*

77. VAN HISE, CHARLES R. The Pre-Cambrian Rocks of the Black Hills.

Geol. Soc. Am., Bull., vol. I, pp. 203-255, pls. 4-5.

States that the slates and schists cannot be divided into two series as given by Newton. Indicates two areas of crystalline schists, the larger lying as a broad zone about the granite, the other in the vicinity of Deadwood. Concludes with Newton that the main mass of the granite is eruptive and that the basic eruptive rocks are older than the granite. Reviews briefly the probable pre-Cambrian history of the Hills. Considers that the quartzites, quartz schists, mica slates, mica schists, and certain of the mica gneisses are of clastic origin, while most or all of the hornblende and chloritic schists are eruptive; that in the original detritus of the micaceous rocks feldspar and quartz were the predominant minerals, but that the detritus of the quartzites and quartz schists contain little feldspar. States that the pre-Cambrian rocks resemble the Huronian iron-bearing series of the Lake Superior region and that they are of undoubted Algonkian age.

78. WALCOTT, CHARLES D. The Fauna of the Lower Cambrian or Olenellus Zone.

U. S. Geol. Surv., 10th Ann. Rept., pp. 515-763, pls. XLIII-XCVIII.

Discusses the Black Hills Cambrian rocks in their relation to other Cambrian areas of North America.

*For this statement of locality see the American Journal of Science, March, 1899, p. 228.

1891.

79. BLAKE, WILLIAM P. Columbite of the Black Hills.
Am. Jour. Sci., vol. XLI, pp. 403-405.
Describes specimens from the Euta and Bob Ingersoll mines and gives measurements and three figures by Professor S. L. Penfield.
80. CLARK, FRANK W. Report of Work Done in the Division of Chemistry and Physics.
U. S. Geol. Surv., Bull. No. 78. 129 pp.
Gives on p. 120 an analysis of a mineral from the Brown tin mine, supposed to be Liebnerite. Analyzed by W. F. Hillebrand and E. L. Howard.
81. GANNETT, HENRY. A Dictionary of Altitudes in the United States (second edition).
U. S. Geol. Surv., Bull. No. 76, 393 pp.
Gives the altitudes of a number of points in the Black Hills and the authority for the same.
82. HEADDEN, W. P. and PIRSSON, L. V. On Black Rutile from the Black Hills.
Am. Jour. Sci., vol. XLI, pp. 249-250.
Describes crystals from the Harney Peak district. One figure and two chemical analyses are given.
83. HEADDEN, WILLIAM P. A New Phosphate from the Black Hills of South Dakota.
Am. Jour. Sci., 3d ser., vol. XLI, pp. 415-417
Gives the physical characters and five chemical analyses of a new phosphate found at the Riverton lode near Harney City, for which the author proposes the name griphite in allusion to its unusual and somewhat enigmatical composition. A phosphate from the Nickel Plate tin claim closely related to Triphylite is also described and two chemical analyses given.
84. MARSH, OTHNIEL C. Geological Horizons as Determined by Vertebrate Fossils.
Am. Jour. Sci. 3d ser., vol. XLII, pp. 336-338, pl. VII.
Mentions the presence of Baptanodon beds in South Dakota.
85. ——— Notice of New Vertebrate Fossils.
Am. Jour. Sci., 3d ser., vol. XLII, pp. 265-269.
The following new species of Brontotheridae are described from

the White River beds: *Allopes crassicornis*, *Brontops validus*, *Titanops medius*.

86. ——— A Horned Artiodactyle (*Protoceras celer*) from the Miocene.

Am. Jour. Sci., 8d ser., vol. XLI, pp. 81-83.

Gives a short description of this the first horned artiodactyle found in the Miocene. Is apparently a true ruminant and nearly as large as a sheep. Found in the upper part of the *Oreodon* beds of the White River basin.

87. THOMPSON, A. H. Administrative Report.

U. S. Geol. Surv., 12th Ann. Rept., pp. 42-53.

Gives on p. 49 an account of astronomical work at Rapid City as a preliminary to future topographic work.

88. WALCOTT, CHARLES D. The Cambrian Group of Rocks in North America.

U. S. Geol. Surv., Bull. 81, Correlation Papers, 447 pp., pls. I-III.

The author reviews on pages 214-216 the results of previous workers in the Black Hills region and on pages 347-349 describes the Black Hills Cambrian as given by Newton, Carpenter and others. The Black Hill region is represented on the maps which show the distribution, relative thickness, etc., of the rocks in the various provinces. The paper by Mr. Edwin James, also the one by Mr. H. Englemann quoted as referring to the Black Hills of Dakota, refer instead to the Laramie mountains, lying within the forks of the Platt river in Wyoming, formerly known as the Black Hills of Wyoming.

89. ——— The North American Continent During Cambrian Time.

U. S. Geol. Surv., 12th Ann. Rept., pp. 529-568, pls XLII-XLV,

Discusses the Black Hills Cambrian area in its relation to other Cambrian areas of North America.

90. WHITE, CHARLES A. A Review of the Cretaceous Formations of North America.

U. S. Geol. Surv., Bull. No. 82, Correlation Papers, 273 pp., pls. I-III.

Makes frequent general mention of the Cretaceous rocks in and around the Black Hills region.

91. WILLIAMS, HENRY S. The Devonian and Carboniferous Formations of North America.

U. S. Geol. Surv., Bull. No. 80, Correlation Papers, 379 pp.

Refers briefly to the Black Hills formations as made out by Meek and Hayden.

1892.

92. CLAYPOLE, E. W. The Tin Island of the Northwest.

Am. Geol., vol. IX, pp. 228-236.

Discusses the general geology of the region with particular reference to the pre-Cambrian rocks. Describes the occurrence of cassiterite and discusses its probable economic importance.

93. DALL, W. H. and HARRIS, G. D. The Neocene of North America.

U. S. Geol. Surv., Bull., No. 84, Correlation Papers, 349 pp.

Describes the White River Miocene chiefly as given by Hayden and Leidy.

94. DAY, DAVID T. Mineral Resources of the United States, Calendar Years 1889 and 1890.

U. S. Geol. Surv., Min. Res., 8vo., 671 pp.

References to Black Hills resources are given as follows: pp. 48-55, gold and silver; p. 80, lead; pp. 119-123, tin; p. 429, sandstone; pp. 465-466 gypsum; p. 474, mica; p. 532, mineral waters.

95. OSBORN, H. F. and WORTMAN, J. L. Characters of Protoceras (Marsh) the New Artiodactyle from the Lower Miocene.

Am. Mus. Nat. Hist., Bull., vol. IV, pp. 351-371, figs. 1-6.

Describes the characters of the species with especial reference to specimens recently found in the White River beds. Discusses the systematic position of the genus and gives a table showing in condensed form the principal characters of the family Protoceratidae with those of the families of the Tragulina and the Pecora.

96. THOMPSON, A. H. Administrative Report.

U. S. Geol. Surv., 13th Ann. Rept., pp. 75-83.

Gives on page 79 an account of topographic work done in the vicinity of Rapid City and Deadwood during the summer of 1891.

97. ULKE, TITUS. A New Tin Mineral in the Black Hills.

Am. Inst. Min. Eng., Trans., vol. XXI, pp. 240-241.

Describes a mineral from the Etta mine containing both copper and tin, to which the name cuprocassiterite is given.

98. VAN HISE, CHARLES R. A Review of the Present State of Knowledge of the Pre-Cambrian Rocks of North America.

U. S. Geol. Surv., Bull. No. 86, Correlation Papers, Archaean and Algonkian, 549 pp., pls. I-XII.

Refers to the Black Hills on pages 257-261, 270 and 503. Gives a short digest of the literature on the Black Hills Algonkian rocks and the conclusions that may be drawn from the work done. Plate VII shows the position of the Algonkian rocks of the Black Hills as related to other North American areas.

99. WALCOTT, CHARLES D. Preliminary Notes on the Discovery of a Vertebrate Fauna in Silurian (Ordovician) Strata.

Geol. Soc. Am., Bull., vol. III, pp. 153-173.

In a footnote on page 173 the author mentions the receipt from Professor F. R. Carpenter of specimens of *Maclurea logani* and *Endoceras accumulatum* collected in the Black Hills, thus establishing the presence of the Trenton in this region.

1893.

100. CLARK, WILLIAM B. The Mesozoic Echinodermata of the United States.

U. S. Geol. Surv., Bull. No. 97, 207 pp., pls. I-L.

Describes and figures a few forms from the Black Hills previously described by others.

101. COUES, ELIOT. History of the Expedition Under the Command of Lewis and Clark, etc.*

Four volumes, 8vo. New York, 1893.

Refers briefly to the topography, climate and geography of the Black Hills region and locates the mountainous area as a single ridge extending from the South Fork of the Cheyenne to a point far beyond the North Fork.

102. DAY, DAVID T. Mineral Resources of the United States, Calendar Year 1891.

U. S. Geol. Surv., Min. Res., 8vo, 630 pp.

Refers to Black Hills mineral resources as follows: pp. 74-80, gold and silver; p. 137, manganese; p. 164, tin; pp. 168-169, nickeliferous pyrrhotite; pp. 580-583, gypsum.

*A number of histories, reports and narratives of this expedition have been issued at different times by various individuals. I have referred only to this one by Professor Coues because it is the best and most recent that has come to my notice.

103. ——— Mineral Resources of the United States, Calendar year 1892.

U. S. Geol. Surv., Min. Res., 8vo, 850 pp.

Refers to Black Hills mineral resources as follows: pp. 50-56 and 69-71, gold and silver; p. 258, tin; p. 749, grindstones.

104. FINLEY, JOHN P. Certain Climatic Features of the Two Dakotas.

Large 8vo, 206 pp., 163 tables, charts and diagrams, Washington.

Makes frequent reference to the climate of the Black Hills region.

105. GANNETT, HENRY. The Average Elevation of the United States.

U. S. Geol. Surv., 18th Ann. Rept., pp. 284-289.

Refers to the height of the Black Hills region.

106. HATCHER, J. B. The Titanotherium Beds.

Am. Nat., March 1 1893, pp. 203-231.

Discusses the origin and authenticity of the name of the beds, their geographical distribution, lithological character, method of deposition of the sediments and the cause of the numerous vertical veins of chalcedony. Notes the finding of a small Miocene deposit near Lead City by Professor W. P. Jenney. States that during the seasons of 1886, '87, '88 the author spent fifteen months in the White River Miocene beds of South Dakota and Nebraska, making extensive collections, the study of which resulted in a separation of the Titanotherium beds into the Lower, Middle and Upper divisions. The most noticeable change in the Titanotherium skeletons is a gradual and decided increase in size from the lowest to the highest beds. A section of the beds accompanies the paper, showing the relative thickness of the three beds with brief descriptions of forms of Titanotheriidae characteristic of each.

107. HEADDEN, WILLIAM P. Stannite and Some of the Alteration Products from the Black Hills, S. D.

Am. Jour. Sci., 3d ser., vol. XLV, pp. 105-110.

Gives physical characters and chemical analyses of minerals from the Peerless and Etta mines.

108. ——— Kehoeite, a New Phosphate from Galena, Lawrence County, S. D.

Am. Jour. Sci., 3d ser., vol. XLVI, pp. 22-24.

Describes an argentiferous galena carrying zinc blende and iron pyrite from the Merritt mine. States that goslarite also occurs in the mine, but not in the immediate vicinity of the Kehoeite. The physical characters and three chemical analyses are given. Named from Mr.

Henry Kehoe, who first observed the occurrence of the mineral. The article includes a "Note on Jarosite," found at the Buxton mine, Lawrence county. One chemical analyses of the latter mineral is given.

109. MCBRIDE, T. H. A New Cycad.

Am. Geol., vol. XII, pp. 248-250.

Describes Bennetites from near Minnekahta, South Dakota.

110. MARSH, OTHNIEL C. Description of Miocene Mammalia.

Am. Jour. Sci., 3d ser., vol. XLVI, pp. 407-412, pls. VII-X.

Describes various species of mammals, among which are the following from the White River basin: *Elotherium*, *crassum*, *E. clavum*, *Ammodon* (*Elotherium*) *bathrodon*, and *Colodon luxatus*.

111. OSBORNE, HENRY F. Rise of the Mammalia in North America.

Am Jour. Sci., 3d ser., vol. XLVI, pp. 448-466, pl. XI. Continued from p. 392.

Reviews the history of previous study of the Mammalia, discusses the classification and gives a table showing the succession of the North American mammals. Various Tertiary types from the White River Miocene are cited.

112. ——— *Aceratherium Tridactylum* from the Lower Miocene of Dakota.

Am. Mus. Nat. Hist., Bull., vol. V, pp. 85-86.

Gives a preliminary description of the fossil named.

113. OSBORNE, H. F. and WORTMAN, J. L. *Artionyx*, a New Genus of Ancylopoda.

Am. Mus. Nat. Hist., Bull., vol. V, pp. 1-18.

Describes a specimen from the *Protoceras* beds of the White River Miocene. Compares the type with other forms, gives a table of the double parallelism of the *Artionychia* and *Perissonychia* and discusses the affinities of the Ancylopoda.

114. POSEPNY, F. The Genesis of Ore Deposits.

Am. Inst. Min. Eng., Trans., vol. XXIII, pp. 197-369.

Mentions the "hysteromorphous deposits" of the Cambrian in the Northern Hills. Refers especially to the paper by Mr. Devereux.

115. STANTON, TIMOTHY W. The Colorado Formation and its Invertebrate Fauna.

U. S. Geol. Surv., Bull., No. 106, 128 pp., pls. I-XLV.

Refers frequently to the geology of the Black Hills region, quoting from previous papers. Describes and figures various fossils collected by others in the vicinity of the Hills.

116. THOMPSON, A. H. Administrative Report.
U. S. Geol. Surv., 14th Ann. Rept., pp. 175-182.
Refers on p. 178 to the survey of the Hermosa quadrangle.
117. WORTMAN, J. L. On the Divisions of the White River or Lower Miocene of Dakota.
Am. Mus. Nat. Hist., Bull., vol. V. pp. 95-105.
Announces the differentiation of the Protoceras beds formerly considered as the upper part of the Oreodon beds. Describes the lithologic character and the fauna of the Lower Miocene beds, gives a stratigraphic table of the formations and reviews the faunal distribution and succession of types.
118. WORTMAN, J. L. and EARLE, CHARLES. Ancestors of the Tapir from the Lower Miocene of Dakota.
Am. Mus. Nat. Hist., Bull., vol. V, pp. 159-180, figs. 1-7.
Announces the discovery of the occurrence of *Protapirus* in the upper part of the White River Miocene, thus placing the origin of the true tapirs in this country below the Oreodon beds and nearly parallel stratigraphically with the European species of *Protapirus*. Discusses the various attempts which have been made to solve the problem of the origin of the tapir in America. Gives a systematic description of the material relating to the American species of *Protapirus* and *Colodon*; also a review of the relationship between the American species of *Protapirus* and those found in Europe, including a resume of the principal characters of the supposed Eocene ancestors of both the *Tapiridae* and *Helaletidae*.
- 1894.
119. CALVIN, SAMUEL. On the Geological Position of *Bennetites dacotensis* Macbride, with Remarks on the Stratigraphy of the Region in which the Species was Discovered.
Ia. Acad. Sci., Proc., vol. I. pt. IV. pp. 18-22. Published also in Am. Geol., Feb. 1894, pp. 79-84.
Gives a detailed discussion of the geological and geographical position of the cycads found in the Southern Black Hills and concludes that *Bennetites dacotensis* belongs to the Cretaceous period and that the horizon which contains the cycads is probably in the uppermost layer of the Dakota sandstone.
120. DAY, DAVID T. Mineral Resources of the United States, Calendar year 1893.
U. S. Geol. Surv., Min. Res., 8vo., 810 pp.
References to Black Hills resources are given as follows: pp. 50-61, gold and silver; p. 132, manganese; pp. 718-719, gypsum. In the

report on gold and silver a table is given in which is indicated the production of gold and silver in the Black Hills during the years 1881-1891.

121. GANNETT, HENRY. Results of Primary Triangulation.

U. S. Geol. Surv., Bull. No. 122, 412 pp., pl. XVII.

Contains on pp. 279-286 and pl. IX an account of work done in the Black Hills under the direction of Mr. E. M. Douglas. Descriptions and positions of the following stations are given: Bear Butte, Custer Peak, Piedmont, Costello, Mitchell, West Base, White, Astronomical Pier in Rapid City court house yard, Sammis, East Base, Dunning, Harney Peak, Thompson Butte, Cheyenne, Gap, Bradley, Fossil, Windy, State Line.

122. HATCHER, J. B. Discovery of Diceratherium, the two-horned Rhinoceros, in the White River Beds of South Dakota.

Am. Geol., vol. XIII, pp. 360-361.

Describes *Diceratherium proavittum* obtained by the Princeton party in 1894, from the Upper Oreadon (*Protoceras*) beds.

123. KNOWLTON, F. H. Fossil Wood from the Black Hills, South Dakota.

Jour. Geol., vol. II, pp. 260-261. [Not seen.]

Describes the structure of the wood of genus *Araucarioxylon*. [W. 135.]

124. MARSH, OTHNIEL C. Eastern Division of the Miohippus Beds, with Notes on some of the Characteristic Fossils.

Am. Jour. Sci., 3d ser., vol. XLVIII, pp. 91-94.

Refers to the White River Miocene as including the Miohippus beds, now generally known in South Dakota as the *Protoceras* beds.

125. ——— Miocene Artiodactyles from the Eastern Miohippus Beds.

Am. Jour. Sci., 3d ser., vol. XLVIII, pp. 175-178.

Describes and figures remains of *Heptacodon gibbiceps*, *Elomeryx armatus* and *Octacodon volens* from the White River Miocene.

126. ——— Description of Tertiary Artiodactyles.

Am. Jour. Sci., 3d ser., vol. XLVIII, pp. 259-274.

Among those given the author describes *Agriomeryx migrans* and *Leptochoerus gracilis* from the White River Miocene.

127. ——— A New Miocene Tapir.

Am. Jour. Sci., 3d ser., vol. XLVIII, p. 348.

Describes a pair of lower jaws found in the Miohippus beds of

South Dakota, which represents an ungulate mammal, probably an ancestor of the modern tapir. The name suggested is *Tanyops indans*.

128. MCBRIBE, THOMAS H. North American Cycads.

Ia. Acad. Sci., Proc., vol. I, pt. IV. pp. 62-65.

Includes a short general discussion of cycads and an account of the development of our knowledge of them in the United States. Refers particularly to the Black Hills cycads and to the manner of learning of their presence there.

129. OSBORN, H. F. and WORTMAN, J. L. Fossil Mammals of the Lower Miocene White River Beds. Collection of 1892.

Am. Mus. Nat. Hist., Bull., vol. VI, pp. 199-228, pls. II-III, figs. 1-8.

The paper is based on collections made during the year 1892. The chief points presented are: New characters of the Lower Miocene rhinoceroses, the osteology of *Metamynodon*, the basi-occipital characters of *Oreodon* as developed in successive horizons, the determination of two species of *Anthracotherium*, and additional characters of the American *Hyopotamus*. A table showing the succession of species in the White River Miocene is also given.

130. PEALE, A. C. The Natural Mineral Waters of the United States.

U. S. Geol. Surv., 14th Ann. Rept., pp. 53-88.

Mentions the Dakota hot springs [Hot Springs, S. D.]

131. PIRSSON, LOUIS V. Phonolitic Rocks from the Black Hills.

Am. Jour. Sci., 8d ser., vol. XLVII, pp. 341-346.

Refers to the information at hand concerning the phonolite of the Black Hills and describes two specimens given the author by individuals who had made little or no observations of field relations. One specimen came from near Deadwood, the other from the Devils Tower. Closes with an earnest suggestion as to the value of further study of the region.

132. SCOTT, WILLIAM B. Notes on the Osteology of *Agriochoerus* Leidy (*Artionyx* O. and W.)

Am. Phil. Soc., Proc., vol. XXXIII, pp. 242-251. [Not seen.]

Describes and figures fragmentary skeletons from the White River bad lands of South Dakota and discusses the systematic position of the genus, (W. 185).

133. ——— Notes on the Osteology of *Ancodus* (*Hyopotamus*).

Geol. Mag., dec. IV, vol. I, pp. 492-493. [Not seen].

Describes the principal characteristics of *Ancodus brachyrhyn-*

chus from material found in the Tertiary beds of South Dakota. (W. 185).

134. TODD, JAMES E. A Preliminary Report on the Geology of South Dakota.

South Dakota Geol. Surv., Bull. No. I, 172 pp. pl. I-V, figs 1-2.

Gives an excellent summary description of the topographic and geologic features of the state including a discussion of the origin, distribution and character of the igneous, metamorphic and sedimentary rocks. An account of the economic geology, a preliminary geological map and a table of the geological formations of the state are also given. Much attention is paid to the geology in the Black Hills region.

135: WARD, LESTER, F. The Cretaceous Rim of the Black Hills.

Jour. Geol. vol. II, pp. 250-266.

Gives a sketch map of the southern foothills, showing locality of cycads near Minnekahta, also various columnar sections and figures. Refers to leaf impressions and silicified wood found at several localities. States that the structure of the wood is well preserved and that it represents apparently an undescribed species of *Aravcarioxylon*. Certain plant forms obtained from the plant beds above Evans quarry are named and are stated to belong apparently to the Dakota group. All plants found below this horizon distinctly indicate a Lower Cretaceous age. The author points out the uncertainty of the dividing line between the Upper and the Lower Cretaceous and discusses the bearing of the facts presented upon the Lower Cretaceous of North America.

136. ——— Fossil Cycadean Trunks of North America with a Revision of the Genus *Cycadeoidea* Buckland.

Biol. Soc. Wash., Bull., vol. IX, pp. 75-87.

Refers to the recent discovery of cycads in the Cretaceous rim of the Black Hills and of its stimulus to the study of these forms in America. Refers briefly to other cycad regions of America and mentions particular localities in the Black Hills. In the revision of the genus Buckland the author gives a bibliography of the genus to which genus apparently all of our American forms belong.

1895.

137. CASE, E. C. On the Mud and Sand Dikes of the White River Miocene.

Am. Geol., vol. XV, pp. 248-254.

Reviews the descriptions of dikes of this character in California, Nebraska and South Dakota. Concludes that the dikes of the White River bad lands occupy pre-existing cracks, which were filled with intrusions of water and suspended materials from below; that the cracks are mud cracks and cracks formed by segregation of the clays around

local centers; that the veins of Chalcedony were formed by the entrance of silicated waters into cracks of similar origin as those containing the dikes; and that the thinning out of the seams from above downward indicates that the silicated waters filtered in from above.

138. GANNETT, HENRY A. A Dictionary of Geographic Positions in the United States.

U. S. Geol. Surv., Bull. No. 123, 183 pp., pl. I.

Gives on p. 121 the latitude and longitude of various places in the Black Hills and the authority for the same.

139. MIDDLETON, JEFFERSON. Statistics of the Clay-Working Industries of the United States.

U. S. Geol. Surv., 16th Ann. Rept., part IV, Min. Res. pp. 517-575.

Gives on pp. 558-559, 568-569, 572-573 analyses of fireclay, brick-clay and terra cotta clay from Rapid City.

140. OSBORN, H. F. and WORTMAN, J. L. Perissodactyles of the Lower Miocene White River Beds.

Am. Mus. Nat. Hist., Bull., vol. VII, pp. 848-875; pls. VIII-XI, figs. 1-12.

Describes and figures almost entire skeletons of *Titanotherium robustum* and *Metamynodon planifrons*. States that the White River horses exhibit a very marked evolution in size from the lower to the higher beds, shows that the true *Lophiodontidae* of Europe are found to be represented in this country by the *Heptodon-Helaletes-Colodon* line previously referred to the *Helaletidae* and indicates the differences between the *Tapir*, *Lophiodon*, and *Hyracus* molar types. A table indicates the stratigraphical position of the species described.

141. PARKER, EDWARD W. Gypsum.

U. S. Geol. Surv., 16th Ann. Rept., part IV, Min. Res., pp. 662-666.

Gives on p. 664 the production of gypsum from South Dakota [Black Hills] for the years 1889, '90, '91, '93, '94.

142. PEARCE, DR. RICHARD. Occurrence of Tellurium in Oxidized Form Associated with Gold.

Col. Sci. Soc., Proc., vol. V. pp. 144-147.

Announces the discovery of tellurium in what is commonly called the Potsdam ore of the Black Hills. Quotes from a letter written by Professor F. C. Smith, who furnished the specimens of ore. Gives a short description of the ore with two analyses, one of oxidized, the other of unoxidized material, showing amounts of gold, silver and tellurium present.

143. ROLKER, CHARLES M. ~~3~~ The Production of Tin in Various Parts of the World.

U. S. Geol. Surv., 16th Ann. Rept., part III, Min. Res., pp. 458-538,

Gives on pages 530-535 a brief review of the development of the tin mines in the Black Hills and of the geology of the tin-bearing districts.

144. ROSEN, REV. PETER. Pahasapah or the Black Hills of South Dakota.

8vo, 645 pp., St. Louis, 1895,

Gives an account of the early history of the Hills. Makes extended references to some of the early expeditions to the region and includes a paper by Professor Franklin R. Carpenter on the Mineral Resources. Refers to some of the writings of Father DeSmet, the Jesuit missionary who visited the Indians in the Black Hills region in the years 1847, 1848, 1851 and 1864, and who is supposed by some to have known of the presence of gold in the Hills several years before it was positively announced by others. Mentions the early establishment of a trading post near where Smithville now stands.

145. SCOTT, WILLIAM B. The Osteology and Relations of Protoceras.

Jour. of Morph., vol. XI, pp. 303-374, pls. XX-XXII. [Not seen.]

Describes the dentition, brain, vertebral column, and limbs of Protoceras, discusses its systematic position, and describes and figures a restoration of Protoceras celer, (W. 146).

146. ——— A Restoration of Hyenodon.

Geol. Mag., dec. IV, vol. II, pp. 441-443, pl. XIIa. [Not seen].

Describes briefly the character of Hyenodon Cruentus, Leidy, from the White River beds of South Dakota, (W. 146).

147. THOMPSON, A. H. Administrative Report.

U. S. Geol. Surv., 15th Ann. Rept., pp. 119-129.

Gives on pages 123-124 an account of topographic work done in the Black Hills region. This includes certain triangulation work, the careful measurement of a base line near Rapid City, and the survey of the Harney Peak and the Oelrich quadrangles.

148. TODD, JAMES E. Recent Geological Work in South Dakota.

Am. Geol., vol. XVI, p. 202.

Gives a short account of field work done in the Black Hills region during the summer of 1895. A fuller account of this work is given in the several papers published in Bulletin No. 2 of the State Geological Survey. See 1898.

149. WALCOTT, CHARLES D. Report of the Director.

U. S. Geol. Surv., 16th Ann. Rept., pp. 7-130.

Refers on p. 41 to a collection of fossil plants obtained by Dr. W. P. Jenney from the Lower Cretaceous of the Black Hills.

150. WARD, LESTER F. Some Analogies in the Lower Cretaceous of Europe and America.

U. S. Geol. Surv., 16th Ann. Rept., pp. 469-542, pls. XCVII-CVII.

Refers to the Lower Cretaceous of the Black Hills and describes and figures a number of cycads obtained from the region. Notes also the Aravcarian structure of specimens of fossil wood from here.

151. WEEKS, JOSEPH D. Manganese.

U. S. Geol. Surv., 16th Ann. Rept., part III, Min. Res., pp. 889-457.

Refers on p. 423 to the production of manganese in Custer county, and gives one analysis.

152. WORTMAN, J. L. On the Osteology of *Agriochaerus*.

Am. Mus. Nat. Hist., Bull., vol. VII, pp. 145-178.

Paper based on fossils from the White River Miocene. Presents an account of the osteology of the *Agriochaerus* together with a critical review of the species which have been described as belonging to it. Gives careful comparisons of *Agriochaerus* with *Oreodon* and shows its similarity to the *Anoplotheridae*. Considers it as an apparent member of the *Artiodactyla*. Gives a table, modified from Professor Cope, showing the analysis of the species and one plate showing restoration of *Agriochaerus latifrons*.

1896.

153. ADAMS, GEORGE I. The Extinct Felidae of North America.

Am. Jour. Sci., 4th ser., vol. I, pp. 419-444, pl. X-XII.

Summarizes the literature on the extinct felidae, adds much new information and proposes a classification for the family. In the White River Miocene the *Titanotherium* beds furnished one species *Dinictis fortis*; the *Oreodon* beds eight, *Dinictis felina*; *D. fortis*, *D. squalidens*, *Hoplophoneus occidentalis*, *H. oreodontis*, *H. robustus*, *H. insolens*, *H. primaevus*; and the *Protoceras* beds two—*Dinictis felina* and *Hoplophoneus insolens*.

154. BEECHER, CHARLES E. Occurrence of Silurian Strata in the Big Horn Mountains, Wyoming and in the Black Hills, South Dakota.

Am. Geol., vol. XVIII, pp. 31-33.

Mentions a visit in 1889 to the Trenton area a few miles southeast

of Deadwood and refers to the fossils mentioned by Mr. Walcott in footnote of Geol. Soc. Am. Bull. vol. III, p. 163. Announces also the presence of Halysites and thus suggests the possible presence of the Niagara in the Hills.

155. BLAKE, WILLIAM P. Gold in Granite and Plutonic Rocks.

Am. Inst. Min. Eng., Trans., vol XXVI, pp. 290-298.

Mentions the occurrence of gold in ancient crystalline gneiss or granitic schists of pre-Cambrian age in the mines of the Homestake group of the Black Hills.

156. DARTON, NELSON H. Notes on the Geology of the Black Hills of Dakota.

Science, New ser., vol. III, pp. 418-419. Abstract of a paper presented before the Geological Society of Washington.

Describes a detailed section made from the base of the Cambrian to the White River Miocene along a line passing through Rapid City.

157. ——— Preliminary Report on Artesian Waters of a Portion of the Dakotas.

U. S. Geol. Surv., 17th Ann. Rept., pt. II, pp. 609-694, pls. LXIX-CVII, figs. 50-65.

Refers briefly to the Black Hills uplift and gives a vertical section from the Black Hills eastward across South Dakota, showing the altitude and relations of the water-bearing strata.

158. FARR, MARCUS S. Notes on the Osteology of White River Horses.

Am. Phil. Soc., Proc., vol. XXXV, pp. 147-175.

The genus *Meshippus* mentioned as occurring in the horizons of White River beds as follows: in *Titanotherium* beds, *M. bairdi*; in *Oreodon* beds, *M. bairdi*, *M. copei*; in *Protoceros* beds, *M. bairdi*, *M. copei*, *M. intermedius*. States that the *Oreodon* beds have furnished most of the best material. The three species are described in considerable detail, and various figures and a diagram are given showing the phylogeny of the horse series as now understood. A bibliography is given, also one plate showing a restoration of *Meshippus bairdi*.

159. GANNETT, HENRY. Magnetic Declination in the United States.

U. S. Geol. Surv., 17th Ann. Rept., vol. I, pp. 211-440.

Gives on pp. 418-414 the declination of the magnetic needle in the various Black Hills counties.

160 HATCHER, J. B. Recent and Fossil Tapirs.

Am. Jour. Sci., 4th ser., vol. I, pp. 161-180, pls. II-V.

Describes a new species of *Protapirus*, *P. vadius*, from the

Protoceras beds of the White River Miocene (Oligocene). Specimens were found four miles south of White River and five miles below the mouth of Porcupine creek, about one mile from the spot where the type of *Protoceras celer* was secured by Mr. H. F. Wells of Sturgis, who was the first to distinguish the *Protoceras* beds, and by whom they were shown to Dr. J. L. Wortman, who was the first to name and describe them. The author adds to our knowledge of the osteology of the genus *Protapirus*, especially to the skull and forelimbs; gives additional characters diagnostic of the various species *Protapirus* and *Colodon*; points out distinctive osteological and dental characters in the skulls of the five generally accepted species of recent tapirs; and reviews previous work of others on the phyllogeny of the *Tapiridae* and *Helaletidae*. The specimens from the White River beds are: *Protapirus validus*, *P. simplex*, *Colodon (Lophiodon) occidentalis* and *C. dakotensis*.

161. MARSH, OTHNIEL C. The Dinosaurs of North America.

U. S. Geol. Surv., 16th Ann. Rept., pp. 143-144, pls II-LXXXV, figs. 1-66.

Describes the caudal vertebrae of *Barosaurus lentus* found near Piedmont, and shows the side, front and bottom views of one of the vertebrae. States that this is the most northern limit now known of the *Atlantosaurus* beds.

162. OSBORN, HENRY F. The Cranial Evolution of *Titanotherium*.

Am. Mus. Nat. Hist., Bull., vol. VIII, pp. 157-197, pls. III-IV, figs. 1-13. diag. I-II.

Studies the evolution of the cranium with the view of distinguishing the influences of sex, of age or growth and of individual variation from the truly retrogressive and progressive characters. Reviews the study of the *Titanotheridae* by others, much of which has to do with White River specimens, gives the principles of cranial and dental evolution, revises and defines the species and indicates their vertical distribution. Concludes that the characters upon which the genera *Symborodon*, *Diconodon*, *Brontops*, *Titanops*, *Allops*, *Haplacodon*, and *Diplocomus* are founded are either marks of sex, age, or individual variability and that these names should not be used.

163. PARKER, EDWARD W. Coal.

U. S. Geol. Surv., 17th Ann. Rept., part III, Min. Res., pp. 285-542.

States on page 515 that South Dakota appears for the first time in 1895 as a coal producer, 200 tons of lignite being mined near Edgemont.

164. RUSSELL, ISRAEL C. Igneous Intrusions in the Neighborhood of the Black Hills of Dakota.

Jour. Geol., vol. IV, pp. 23-43.

Contrasts these intrusions with those of the Henry mountains described by Mr. Gilbert, and those of New Mexico described by Col.

Dutton. Gives three plates of two figures each and describes the following: Little Sundance dome, Sundance hill, Mato Tepees or Devils Tower, the Little Missouri Buttes, Inyan Kara, Bear Butte, Crow Peak, Terry and Custer Peaks and Warren Peak. States that all have a common history. Refers to them as plutonic plugs and indicates that each owes its existence to the injection from beneath of a column of molten rock into stratified beds and the subsequent removal of the enclosing sedimentary strata so as to expose, with one exception the inner core of plutonic rock. Notes the absence of dikes and faults in immediate connection with plutonic plugs. Points out the similarity between the domes of sedimentary beds raised above the plugs and the far greater dome from which the Black Hills have been sculptured.

165. ——— On the Nature of Igneous Intrusions.

Jour. Geol., vol. IV, pp. 177-194.

Describes the several forms of igneous intrusions and discusses their origin. Cites the Black Hills region for various examples.

166. SMITH, FRANK C. The Occurrence and Behavior of Tellurium in Gold Ores. More Particularly with Reference to the Potsdam Ores of the Black Hills, South Dakota.

Am. Inst. Min. Eng., Trans., vol. XXV, pp. 485-515, figs. I-II. Discussion in same volume, pp. 1103-1108.

States that the discovery of tellurium in the Potsdam ores of the Black Hills was first made in specimens from the Welcome mine. Eleven photomicrographs of ores are given. Much of the paper is taken up with discussions of metallurgical processes.

167. VAN HISE, CHARLES R. Principles of North American Pre-Cambrian Geology.

U. S. Geol. Surv., 16th Ann. Rept., pp. 581-848, pls. CVIII-CXVI, figs. 101-162.

Discusses the nature of dikes and veins in the granite district of the Black Hills. States that the Black Hills afford one of the best instances known of the metamorphic effect of great intrusive masses of granite and that the production of peripheral cleavage parallel to an intrusive magma, and therefore normal to the pressure, is as fluently illustrated here as anywhere in America.

168. WIELAND, GEORGE R. Archelon ischyros; A New Gigantic Cryptodire Testudinate from the Fort Pierre Cretaceous of South Dakota.

Am. Jour. Sci., 4th ser., vol. II, pp. 399-412, pl. VI.

Gives description and relationship of a specimen that was found in the uppermost Fort Pierre, southeast of the Black Hills, near the South Fork of the Cheyenne.

1897.

169. BECKER, GEORGE F. The Witwatersrand Banket, With Notes on Other Gold-Bearing Pudding Stones. U. S. Geol. Surv., 18th Ann. Rept., part V, Min. Res., pp. 153-184. Refers briefly on p. 180 to the Black Hills gold-bearing conglomerate and notes its similarity to the Witwatersrand banket.
170. DAHL, WILLIAM H. A Table of the North American Tertiary Horizons, Correlated with One Another and With Those of Western Europe, With Annotations. U. S. Geol. Surv., 18th Ann. Rept., pt. II, pp. 827-848. The positions of the various White River beds are given, with notes on the same.
171. DAY, DAVID T. Mineral Resources of the United States, 1896. U. S. Geol. Surv., 18th Ann. Rept., part V. Min. Res. Refers on pp. 1351-1353 to the occurrence and production of fullers earth in the Black Hills. Two analyses and two columnar sections are given.
172. EMMONS, SAMUEL F. The Geology of Government Explorations. (Presidential Address Delivered Dec. 16, 1896). Geol. Soc. Wash., 8vo, pp. 8-39. Science, n. s., vol. V, pp. 1-15, 42-51. Mentions some of the more important expeditions to the Black Hills region and includes in the accompanying bibliography a list of the resulting publications.
173. FRAZER, PERSIFOR. Notes on the Northern Black Hills of South Dakota. Am. Inst. Min. Eng., Trans., vol. XXVII, pp. 204-231, pls. I-III. Discusses the general economic geology of the Northern Black Hills, with especial reference to the Galena District. A short list of papers on the economic and structural geology of the region is given.
174. HATCHER, J. B. Diceratherium Proavitu. Am. Geol., vol. XX, pp. 313-316. Corrects some typographical errors in the article referring to this fossil in the Am. Geol., vol. XIII, pp. 360-361, 1894, and gives reasons for placing the form in the genus Diceratherium rather than aceratherium.

175. MARSH, OTHNIEL C. Principal Characters of the Protoceridae, Part I.

Am. Jour. Sci., 4th ser., vol. IV, pp. 165-176, pls. II-VII, figs. 1-7.

Describes and figures male and female skulls of Protoceras, also describes and figures the skull and dentition of Calops.

176. ORTMAN, ARNOLD E. New Species of the Palinurid Genus Linuparus found in the Upper Cretaceous of Dakota.

Am. Jour. Sci., 4th ser., vol. IV, pp. 290-297.

Describes and figures two specimens collected by Mr. Wells from the Niobrara group at the head of Cottonwood creek, Meade county. These represent the first remains of this group of Decapoda found on the American continent and surpasses in completeness of preservation anything that is known of this group in the European deposits.

177. RIES, HEINRICH, The Fullers Earth of South Dakota.

Am. Inst. Min. Eng., Trans., vol. XXVII, pp. 333-335.

Describes the fullers earth from near Fairburn, Argyle, Minnekahta and other localities and discusses its probable economic value. Six analyses are given.

178. SCOTT, SAMUEL. Map of the Black Hills of South Dakota and Wyoming with Full Descriptions of Mineral Resources, etc.

Sm. 8vo, 40 pp., map, 1897, Custer City, S. D.

Gives brief descriptions of the formations, rocks and minerals of the Black Hills and notes the place of occurrence of many of the minerals. A colored map, scale of five miles to the inch, shows the areal distribution of the formations.

179. SMITH, FRANK C. The Potsdam Gold Ores of the Black Hills of South Dakota.

Am. Inst. Min. Eng., Trans., vol. XXVII, pp. 404-423, map.

Discusses the general and economic geology of the Northern Connected district, with short reference to the Galena district.

180. STANTON, TIMOTHY W. A Comparative Study of the Lower Cretaceous Formations and Faunas of the United States.

Jour. Geol., vol. V, pp. 579-624.

Refers in a general way to the Black Hills region and particularly

to the Black Hills *Atlantosaurus* beds. Gives a bibliography, a number of the papers of which refer to the Black Hills region.

181. DAY, WILLIAM C. Stone.

U. S. Geol. Surv., 19th Ann. Rept., part VI, continued, Min. Res., pp. 205-309.

Gives on p. 278 the crushing strength of six kinds of sandstone quarried at Rapid City.

1898.

182. DILLER, JOSEPH S. The Educational Series of Rock Specimens, Collected and Distributed by the United States Geological Survey.

U. S. Geol. Surv., Bull. No. 150, 400 pp.

The following Black Hills Rocks are described: Phonolite, described by Mr. Whitman Cross, and Mica-Schist (Tourmaline-Biolite-Schist), described by Mr. W. S. Bayley.

183. FARRINGTON, O. C. [Report to the Director].

Field Columb. Mus., Ann. Rept. of the Director, Report Series, vol. I, No. 4, pp. 263-343.

Gives on pages 277-278 a brief account of the work of the party sent by the museum in 1898 under the author's direction to the White River bad lands, where seven weeks were spent in making collections of fossils.

184. MARSH, OTHNIEL C. Cycad Horizons in the Rocky Mountain Region.

Am. Jour. Sci., vol. VI, p. 197.

Gives a short review of our knowledge of the cycad horizons of the West, with particular reference to the Black Hills localities.

185. ——— Jurassic Formation on the Atlantic Coast—
Supplement.

Am. Jour. Sci., 4th ser., vol. VI, pp. 105-115.

Under the head of "Cycad Horizons" the author makes brief mention of the numerous and well-preserved cycads of the Black Hills.

186. OSBORNE, HENRY F. The Extinct Rhinoceroses.

Am. Mus. Nat. Hist., Mem., vol. I, pt. III, pp. 75-164, pls. XIIa-XX, 49 figs.

Part of a memoir which endeavors to establish a sound philosophical basis for the morphology of the rhinoceroses, derived from their primitive, parallel and divergent characters, and leading toward the discovery of their origin, phylogeny and distribution. This part of the

memoir is based mostly on a study of the skull and teeth. Makes frequent reference to specimens from the White River basin, some of which are figured.

187. TODD, JAMES E. First Biennial Report of the State Geologist.

South Dakota Geol. Surv., Bull. No. 2, pp. 1-13. Dated October 29, 1894.

Contains information in regard to the author's field work in the Black Hills region during the year 1894.

188. ——— Second Biennial Report of the State Geologist.

South Dakota Geol. Surv., Bull. No. 2, pp. 15-24. Dated October 31, 1896.

Contains information in regard to the author's field work in the Black Hills region during the year 1895.

189. ——— Section Along Rapid Creek from Rapid City Westward.

South Dakota Geol. Surv., Bull. No. 2, pp. 27-40, pls. II-IV.

Gives the purpose and history of the work and the reasons for choice of location. Describes the geological formation along the section, indicates three or four terraces and gives economic notes on certain resources. Notes the finding of fossils in the Purple limestone and describes the complex folding in the Algonkian slates.

190. ——— A Reconnaissance Into Northwestern South Dakota.

South Dakota Geol. Surv., Bull. No. 2, pp. 43-68, pls. V-X.

Describes the topography, altitude, drainage, and geologic features of the area and gives a number of columnar sections. Notes the presence of White River and Loup Fork Miocene beds overlying the Laramie in Harding, Butte and Ewing counties, an area of considerable disturbance in Harding county and lignite beds of importance in Ewing, Hardin and Martin counties. Economic notes on the various resources are given.

191. ——— The Geology Along the Burlington and Missouri Railway.

South Dakota Geol. Surv., Bull. No. 2, pp. 69-82.

Describes the geological features of the Hills along the railway, beginning with Ardmore, near the southern limit of the state and continuing northward to Deadwood and to Spearfish.

192. ——— Elevations In and About the Black Hills.

South Dakota Geol. Surv., Bull. No. 2, pp. 83-87.

Gives heights of 164 localities in the Black Hills region, the

authorities for which are the Oelrich, Hermosa, Rapid, Deadwood and Custer topographic sheets published by the United States Geological Survey and the railroad profiles of the Burlington and Missouri Valley railway.

193. ——— Additional Notes on the Limits of the Main Artesian Basin.

South Dakota Geol. Surv., Bull. No. 2, pp. 88-115.

Reference is made to the relation of the Black Hills region to the main artesian basin.

194. ——— The Exploration of the White River Bad Lands in 1896.

South Dakota Geol., Surv., Bull. No. 2, pp. 117-135, pls. XII-XV.

Briefly describes the topography and designates five base levels of erosion. Gives notes on the various formations, discusses the life of the Miocene and the geological history of the Tertiary and post-Tertiary age. Refers to the volcanic ash stratum found in Cedar and Sheep mountains and treats of the economic resources of the region.

195. WALCOTT, CHARLES D. Report of the Director.

U. S. Geol. Surv., 19th Ann. Rept., pt. I, 422 pp.

Gives on p. 56 a short account of field work by the Director in the Black Hills in August, 1897. Refers on p. 94 to triangulation work in the Black Hills forest reserve, including the location of a meridian line at Deadwood. The elevations and exact locations of all bench marks determined on the Deadwood, Hermosa, Rapid and Harney Peak quadrangles are given on pages 281-314.

196. WARD, LESTER, F. Descriptions of the Species of Cycadeoidea, or Fossil Cycadean Trunks, thus far Determined from the Lower Cretaceous Rim of the Black Hills.

Gives a description of twenty-one species, twenty of which are new to science. The paper is the result of a careful study of a collection of one hundred and fifty-five Black Hills specimens belonging to the following named institutions: twenty-five to the United States National Museum, two to the State School of Mines, two to the Womans College of Baltimore and one hundred and twenty-six to Yale University.

197. WIELAND, GEORGE R. The Protostegan Plastron.

Am. Jour. Sci., 4th ser., vol. V, pp. 15-20, pl. II.

Describes and figures two specimens from the uppermost Fort Pierre Cretaceous near the Cheyenne river. The type name Archelon ischyros is abandoned and Protostega ischyra used instead.

1899.

198. CASE, E. C. The Development and Geological Relations of the Vertebrates. V. Mammalia, Continued. Jour. Geol. vol. VII, pp. 163-187,
Refers frequently to fossils from the White River bad lands.
199. DARTON, NELSON H. Bad Lands of South Dakota. Nat. Geog. Mag., vol. X, pp. 339-343, 4 plates,
Gives a short description of the White River bad lands and directs how the region may be most conveniently reached.
200. ——— Jurassic Formations of the Black Hills of South Dakota.
Geol. Soc. Am., Bull., vol. 10, pp. 383-396, pls. 42-44.
The author reviews previous investigations of the Jurassic rocks of the Black Hills, indicates the uncertainty of the Jurassic-Cretaceous contact, gives a table showing the classification, composition and nomenclature of the Jurassic and adjoining formations, also several columnar sections and a list of fossils thus far reported and outlines the history of the Black Hills Jurassic deposits.
201. DAY, DAVID T. Gold and Silver.
U. S. Geol. Surv., 20th Ann. Rept., vol. 6, Min. Res., pp. 103-111.
Gives the production of gold and silver in the Black Hills for 1896, 1897, 1898
202. EASTMAN, C. R. Jurassic Fishes from Black Hills of South Dakota.
Geol. Soc. Am., Bull., vol. 10, pp. 397-408, pls. 45-48.
Describes and figures specimens of *Pholidophorus americanus*, *Amiopsis? dartoni* and an undetermined ganoid, all of which were collected in 1893 by Mr. N. H. Darton from the basal Jurassic near Hot Springs.
203. FARRINGTON, OLIVER C. A Fossil Egg from South Dakota.
Field Columb. Mus., geol. ser., vol. I, pp. 193-200, pls. XX-XXI.
Describes a supposed petrified egg of an anatine bird of early Miocene age, found by Mr. Kelly Robinson, of Dakota City.
204. GANNETT, HENRY. The Forests of the United States
U. S. Geol. Surv., 19th Ann. Rept., pt. V, pp. 1-66, pls. V-XIII.
Gives statistics of the Black Hills lumber supply and on pp. 49-53 briefly describes the Black Hills reserve.
205. GRAVES, HENRY S. Black Hills Forest Reserve.
U. S. Geol. Surv., 19th Ann. Rept., pp. 67-164, pls. XIX-XXXVI, map.
Gives the limits of the reserve and describes the topography of the region. Indicates the lands suitable for agricultural, grazing

and mining purposes, and the character, distribution, condition and yield of the forest covered areas. Gives sources of injury to the forests, discusses the reproduction, growth and yield of the yellow pine, suggests method of management and gives a detailed description of the forest as developed along the various streams of the Hills. A map accompanying the paper shows the land classification and density of standing timber in the Rapid, Deadwood, Sundance, Hermosa and Harney Peak quadrangles.

206. HOLMES, J. A. Mica Deposits in the United States.

U. S. Geol. Surv., 20th Ann. Rept., vol. 6, continued, Min. Res., pp. 691-707.

Makes frequent reference to the mica of the Black Hills, giving a brief account of its mode of occurrence, nature of the deposits, quantity, distribution, quality and value of the mica, structure, origin, and minerals of the mica dikes and methods of prospecting and mining. Gives the present condition of the mica industry in the Hills and indicates its probable future development.

207. IRVING, JOHN D. A Contribution to the Geology of the Northern Black Hills.

Contributions from the Geological Department of Columbia University, vol. IX, No. 65. [Annals N. Y. Acad. Sci., vol. XII, No. 9, pp. 187-340, pls. V-XVI, figs. 5-20.]

Gives a detailed account of the geology of a portion of Lawrence county, the area chiefly concerned being about eight miles square and situated in the northwestern part of the Deadwood quadrangle. The paper includes a discussion of the topography, stratigraphy, eruptive rocks and ore bodies of the region. The eruptive rocks are described as: Intrusions in the Algonkian, intrusions in the Cambro-Silurian, and intrusions in the Carboniferous. Of these the first shows only dikes, they being of two distinct varieties: pre-Cambrian dikes of amphibolite and hornblende schist and dikes of phonolite, quartz-porphyry, etc., of early Tertiary time. The second shows laccolites, sheets and dikes. The third includes thick, irregular masses, not properly classed as dikes, sheets, or laccolites, but apparently belonging to none or to all three of these types. The views of previous writers on the eruptive rocks of the Hills are given with reference to the causes influencing the formation of the various kinds of intrusions. The author considers that the influences of the rocks into which the magmas are intruded are the most important, and in the Northern Black Hills this has been the case almost without exception. A detailed description of the petrography and areal distribution of the eruptive rocks is given, the following rocks being determined: Quartz-aegirite-porphyry, mica-diorite-porphyry, dacite, tonalite and augite-vogesite of the post Cretaceous age and various amphibolites of pre-Cambrian age. The

author also describes the ores of the area, attention being given chiefly to the siliceous ores of the Cambro-Silurian and the Carboniferous formations and discusses the probable method of their formation. A map showing the areal distribution of the formations accompanies the paper.

208. MARSH, OTHNIEL C. Footprints of Jurassic Dinosaurs,

Am. Jour. Sci., 4th ser., No. 39, pp. 227-232, pl. V.

Describes and figures the first footprints found in Jurassic strata in this country. They are all tridactyl and were found by Mr. Wells in 1898 in the *Atlantosaurus* beds on the southwestern border of the Black Hills. The author also discusses the various post-Paleozoic strata of the Hills region and gives a table including the characteristic fossils of the various horizons.

209. MATTHEW, W. D. Is the White River Tertiary an Aeolian Formation?

Am. Nat., vol. XXXIII, pp. 403-408.

States objections to the Lacustrine hypothesis with especial reference to the stratigraphy and the fauna. Advances the theory that the deposits are chiefly aeolian, similar in origin to the prairie loess but that the sandstones are perhaps mostly fluvial.

210. O'HARRA, CLEOPHAS C. and FORSYTH, A. Notes on the Geology and Mineral Deposits of a Portion of the Southern Black Hills.

South Dakota School of Mines, Bull., 41 pp., 11 figs.

Discusses the general geology, mineralogy and mining interests of an area southeast of Harney Peak, near the eastern limit of the granite district.

211. PARKER, EDWARD W. Gypsum.

U. S. Geol. Surv., 20th Ann. Rept., vol. 6, continued, Min. Res., pp. 657-666

Gives statistics of the gypsum of the United States and other parts of the world and on page 661 gives the total production and value of gypsum in South Dakota [Black Hills] during the past ten years.

212. TALLENT, ANNIE D. The Black Hills; or the Last Hunting Ground of the Dakotahs.

8vo XXII and 713 pp., St. Louis, 1899.

An interesting popular history of the Black Hills since 1874. Written by the first woman to enter the Black Hills for the purpose of settlement. Contains many general references to the geology and geography of the region.

213. WARD, LESTER F. The Cretaceous Formation of the Black Hills as Indicated by the Fossil Plants, with the Collaboration of Walter P. Jenney, William M. Fontaine and F. H. Knowlton.

U. S. Geol. Surv., 19th Ann. Rept., pt. II, pp. 521-946, pls. 57-172.

An exhaustive report on the Cretaceous rim of the Black Hills, particularly the Lower Cretaceous, as interpreted by the plants discovered, the most important of which are cycads. Gives a historical review of our knowledge of the Cretaceous of the Black Hills, indicate the Lower Cretaceous age of a considerable series of strata below the Dakota sandstone, describes the Cretaceous flora, particular attention being given to the cycads, and gives in detail the geology of the Minnekahta, the Black Hawk and the Hay Creek regions. Numerous sections are given, including a general section of the Hay Creek coal field and a general section of the strata occurring in the Black Hills, the latter section showing the position, age, divisions, origin and mode of occurrence and the lithologic and water-bearing character of the various strata. Professor Jenney contributes the field observations in the Hay Creek coal field, and Professor Fontaine the notes on the Lower Cretaceous plants from the same field. Dr. Knowlton describes the fossil wood. A table gives the foreign, the American and the Black Hills distribution of eighty-six species of cretaceous plants, most of which are figured.

214. WIELAND, GEORGE R. A Study of Some American Fossil Cycads, Part I, the Male Flower of Cycadeoidea.

Am. Jour. Sci., 4th ser., March, pp. 219-226, pls. II-IV.

Describes the male flower of *Cycadeoidea ingens* from the Black Hills and gives reference to the Black Hills literature.

215. ——— A Study of Some American Fossil Cycads, Part II. The Leaf Structure of Cycadeoidea.

Am. Jour. Sci., 4th ser., No. 40, pp. 305-308, pl. VII.

Discussion based largely on specimens from the Black Hills.

216. ——— A Study of Some American Fossil Cycads, Part III. The Female Fructification of Cycadeoidea.

Am. Jour. Sci., 4th ser., No. 41, pp. 383-391, pls. VIII-X

Compares American and European Cycads and describes particularly the fructification of certain Black Hills cycads.

217. ——— Cycadean Monoecism.

Am. Jour. Sci., 4th ser., No. 44, p. 164.

Discusses various examples of monoecism as shown in specimens from the Black Hills.

Index to Names of Authors and Collectors.

The light-faced figures indicate the page. the black-faced figures the number of entry in the bibliography.

- | | |
|--|--|
| <p>Adams, G. I., 153.
 Astor, J. J., 9.
 Austin, E. P., 22.
 Bannon, F. M., 42.
 Bayley, W. S., 182.
 Becker, G. F., 169.
 Beecher, C. E., 154.
 Blake, W. P., 45, 49, 52, 53, 55, 79, 155.
 Calvin, Samuel, 119.
 Carpenter, F. R., 88, 84, 85, 60, 61, 88, 99.
 Case, E. C., 137, 198.
 Caswell, J. H., 29, 34.
 Chance, H. M., 69.
 Clark, F. W., 70, 80.
 Clark, W. B., 100.
 Clark, Wm., 7, 101
 Claypole, E. W., 92.
 Cope, E. D., 33, 35, 40, 41, 46, 152.
 Coues, Eliot, 65, 101.
 Crosby, W. O., 83, 62, 63.
 Cross, F. J., 73.
 Cross, Whitman, 182.
 Culbertson, T. A., 78.
 Custer, G. A., 7, 11, 22.
 Dall, W. H., 93, 170.
 Darton, N. H., 48, 44, 156, 157, 199, 200.
 Day, D. T., 58, 64, 71, 94, 102, 103, 120, 171, 181, 201.
 Denton, Prof., 47.
 DeSmet, Father, 144.
 Devereux, W. B., 42, 54.
 Diller, J. S., 182.
 Dodge, R. I., 25, 29, 29.
 Douglas, E. M., 42.
 Dunnington, A. F., 41.
 Dutton, Col., 164.</p> | <p>Eakins, L. G., 70.
 Earle, Chas., 118.
 Eastman, C. R., 202.
 Emmons, S. F., 54, 172.
 Englemann, H., 8, 88.
 Evans, John, 7, 19, 18, 4, 6.
 Farmer, R. A., 42.
 Farr, M. S., 158.
 Farrington, O. C., 41, 183, 203.
 Finley, J. P., 104.
 Fitch, C. H., 42.
 Fontaine, W. M., 48, 213.
 Forsyth, A., 210.
 Frazer, Persifor, 33, 85, 173.
 Gannett, Henry, 41, 81, 105, 121, 138, 159, 204.
 Gilbert, G. K., 28, 164.
 Graves, H. S., 48, 205.
 Gray, Asa, 29.
 Grinnell, G. B., 22, 21.
 Hall, James, 14.
 Harney, W. S., 14.
 Harris, G. D., 93.
 Hatcher, J. B., 84, 41, 106, 122, 160, 174.
 Hayden, F. V., 18, 14, 17, 18, 21, 22, 27, 31, 38, 7, 9, 10, 11, 13, 14, 16, 22, 30, 40, 43, 91, 93.
 Headden, W. P., 72, 73, 82, 83, 107, 108.
 Hillebrand, W. F., 80.
 Holmes, J. A., 206.
 Howard, E. L., 80.
 Humphreys, A. A., 22, 26.
 Hunt, W. P., 9, 11.
 Irving, Washington, 9.
 Irving, J. D., 37, 207.</p> |
|--|--|

- James, Edwin, 8, 88.
 Jenney, W. P., 7, 17, 25, 26, 29, 30, 43, 29, 36, 37, 54, 106, 149, 212.
 Kehoe, Henry, 108.
 King, Clarence, 44.
 Knowlton, F. H., 43, 123, 213.
 Leldy, Joseph, 10, 13, 14, 3, 6, 15, 17, 18, 20, 93.
 Lesquereux, Leo, 47.
 Lewis, Meriweather, 7, 101.
 Ludlow, Wm., 22, 23.
 McBride, T. H., 47, 109, 119, 128.
 M'Gillycuddy, V. T., 25.
 Maguire, H. N., 9, 31.
 Marsh, O. C., 33, 24, 25, 59, 65, 74, 75, 76, 84, 85, 86, 110, 124, 125, 126, 127, 161, 175, 184, 185, 208.
 Matthew, W. D., 209.
 Meek, F. B., 13, 14, 21, 10, 11, 30, 91.
 Middleton, Jefferson, 139.
 Newberry, J. S., 19.
 Newton, Henry, 7, 15, 17, 21, 25, 26, 29, 30, 34, 35, 39, 29, 38, 54, 63, 88.
 O'Harra, C. C., 210.
 O'Loughland, Prof., 6.
 Ortman, A. E., 176.
 Osborn, H. F., 95, 111, 112, 113, 129, 140, 162, 186.
 Owen, D. D., 13, 19, 3, 4, 5, 6.
 Parker, E. W., 8, 15, 141, 163, 211.
 Patrick, W. F., 25.
 Peale, A. C., 130.
 Pearce, Richard, 73, 142.
 Penfield, S. L., 79.
 Pirsson, L. V., 82, 131.
 Poe, E. A., 10.
 Posepny, F., 114.
 Post, W. S., 42.
 Prout, H. A., 10, 1, 2, 6.
 Reynolds, W. F., 11, 13, 21, 10, 12, 13.
 Reeves, R. B., 30.
 Ries, Heinrich, 177.
 Robinson, Kelly, 203.
 Rolker, C. M., 143.
 Rosen, Peter, 144.
 Russell, I. C., 164, 165.
 Schaeffer, C. A., 50, 51.
 Scott, W. B., 41, 132, 133, 145, 146.
 Scott, Samuel, 178.
 Shumard, Dr., 13.
 Smith, F. C., 142, 166, 179.
 Stanton, W. S., 7, 11, 29, 30, 32, 115, 180.
 Tallent, A. D., 212.
 Thompson, A. H., 87, 96, 116, 147.
 Todd, J. E., 37, 134, 148, 187, 188, 189, 190, 191, 192, 193, 194.
 Tuttle, H. B., 25, 29, 30.
 Ulke, Titus, 97.
 Valle, Mr., 8.
 Van Hise, C. R., 33, 77, 98, 167.
 Vosburg, Theodore, 73.
 Walcott, C. D., 34, 78, 88, 89, 99, 149, 154, 195.
 Wallace, H. S., 42.
 Ward, L. F., 10, 43, 66, 135, 136, 150, 196, 213.
 Warren, G. K., 8, 11, 14, 17, 23, 7, 8, 9, 11, 22, 26, 67.
 Weeks, J. D., 45, 151.
 Wells, H. F., 160, 176.
 Wheeler, G. M., 22, 68.
 White, C. A., 56, 90.
 Whitfield, R. P., 29, 27, 39.
 Wileland, G. R., 168, 197, 214, 215, 216, 217.
 Williams, Albert, 48, 55, 57, 91.
 Williams, H. S., 91.
 Wiltse, Chauncey, 22.
 Winchell, N. H., 22, 28, 47.
 Wortman, J. L., 34, 41, 95, 113, 117, 118, 129, 140, 152, 160.

SOUTH DAKOTA SCHOOL OF MINES

BULLETIN NO. 6.

DEPARTMENT OF GEOLOGY.

THE MINERAL WEALTH
OF THE
BLACK HILLS.

BY CLEOPHAS C. O'HARRA.

[Published also as a Part of Bulletin No. 3 of the South Dakota Geological Survey.]

RAPID CITY, SOUTH DAKOTA.

JANUARY, 1892.



LETTER OF TRANSMITTAL.

SOUTH DAKOTA SCHOOL OF MINES, }
RAPID CITY, January 20, 1902. }

SIR:—I have the honor to transmit herewith a paper by Dr. Cleophas C. O'Harra, entitled "The Mineral Wealth of the Black Hills." The paper contains much of economic and educational importance, and should prove of substantial value to all who may be interested in the Black Hills region.

I submit the paper with the recommendation that it be published as Bulletin No. 6 of the South Dakota School of Mines.

Very respectfully,

ROBERT L. SLAGLE, President.

HON. FREDERICK A. SPAFFORD,
President Regents of Education.

CONTENTS.

	Page
PREFACE	9
INTRODUCTORY	II
GENERAL GEOLOGY.....	II
HISTORICAL REVIEW.....	16
MINERAL PRODUCTS.....	20
GOLD	20
Classification of Ores.....	20
Vein Quartz Ores.....	21
Auriferous Pyrite Veins	24
Auriferous Dikes, Slate Breccias and Fissure Veins.....	25
Impregnated Zones.....	27
Conglomerate or Cement Ores.	32
Cambrian Siliceous Ores.....	37
Carboniferous Siliceous Ores.....	46
Placer Deposits.....	50
Tailings.....	54
Methods of Treatment.....	55
Output.....	56
Future Prospects.....	56
COPPER	57
IRON	61
MANGANESE.....	63
SILVER AND LEAD.....	63
TIN	66
TUNGSTEN	71
GRAPHITE.....	75
MICA	75
SPODUMENE.....	77
MISCELLANEOUS MINERALS	80
RESUME OF MINERAL PRODUCTION.....	81
CONCLUSION.....	81
INDEX	83

ILLUSTRATIONS.

	Opp.	Page
PLATE 1. Custer on French Creek.....	11	
" 2. The Holy Terror and Keystone Mines, Keystone...	20	
" 3. The Uncle Sam Mine, Hoist and Mill, Perry.....	24	
" 4. Part of one of the Homestake Open Cuts, Lead....	28	
" 5. Lead City.....	28	
" 6. Blacktail Gulch, Gayville... ..	32	
" 7. Ruby Basin, looking west from Sugar Loaf Hill...	36	
" 8. Porphyry Dikes in Algonkian Slates.....	40	
" 9. Cambrian Quartzite with Intercalated Porphyry resting on Algonkian Slates.....	40	
" 10. Porphyry Needles at Top of Johnston's Peak, near Bear Gulch.....	40	
" 11. East-West Section through Tornado Shaft, Terry	42	
" 12. Middle Cambrian Shales and Sandstones, Deadwood	44	
" 13. Stewart Mine on Lower Quartzite, near Terry.....	46	
" 14. Deadwood.....	52	
" 15. Homestake Mills, Hoists and Open Cuts, at Lead	56	
" 16. The Golden Reward Smelter, Deadwood	56	
" 17. The Kildonan Chlorination Plant, and Deposit of Homestake Tailings	56	
" 18. The Cleopatra Mine and Cyanide Plant.....	56	
" 19. The Etta Mine. near Keystone	68	
" 20. The Hidden Fortune Mine, near Lead....	72	
" 21. The McMackin Mine, near Custer.....	76	
" 22. Spodumene Crystals, Etta Mine, near Keystone...	78	

	Page
FIGURE 1.	34
" 2.	41
" 3.	49

PREFACE.

This paper describes briefly the economic mineral deposits of the Black Hills of South Dakota, and includes also a general summary of the history, conditions, and apparent possibilities of their development.*

The funds and time available in the preparation of the paper have given opportunity for little original investigation. Many mines were not visited and none could be examined thoroughly, hence no effort is made to enter into their detailed description. I have, however, visited representative properties in practically every mining district within the Hills, and thus have personally acquainted myself in the field with the general nature of the deposits. The field work was chiefly done during a portion of the past summer, under the direction of the South Dakota Geological Survey. I have used also such information as it has been possible to collect in connection with my regular duties at the South Dakota School of Mines. All of this has been supplemented by careful consultation of the geological literature of the region.

I have in special cases referred by footnote, or otherwise, to authors whose ideas I have used or whose words I have quoted. The discriminating reader will doubtless note other places where the treatment is much the same as given by earlier writers. I have not considered it necessary in such cases to make specific acknowledgement. Those wishing to consult the earlier papers will find a fairly complete list of the literature, up to and including the year 1899, in Bulletin No. 4 of the South Dakota School of Mines.

One feature of the work has given me much satisfaction, and for this I wish to express my appreciation. It is the uniform courtesy extended me by mine owners when visiting their properties. These visits to the mines, as well as the examination of maps of underground workings, have brought to me many facts which cannot be given here, but whose influence will be felt, nevertheless, in that their observation has aided greatly in elucidating the description of the various deposits.

*Structural materials and water resources are not discussed in this paper, they being reviewed elsewhere by Professor J. E. Todd, State Geologist.



PHOTOGRAPH BY O'HARRA, 1901.

CUSTER, ON FRENCH CREEK.

Gold first discovered in the Black Hills in placer diggings near logs at corner of fence.

THE MINERAL WEALTH OF THE BLACK HILLS

BY CLEOPHAS C. O'HARRA.

INTRODUCTORY.

The first quarter century of active mining operations in the Black Hills has little more than closed. Considerable prospecting was done within the region in 1875, but operations of a permanent character did not begin until the opening of the following year. From an isolated and practically unknown mountainous, forest-clad island in the midst of a vast, treeless plain, and within the confines of a great Indian reservation, the Black Hills region has, during its brief history, become one of the most important precious metal producers of the United States. Railways have brought the region to the threshold of older communities, beautiful scenery peculiar to the country annually attracts its thousands, permanent homes, prosperous towns and productive ranches prevail, and mining facilities are in many ways unsurpassed. Gold found throughout the region, but obtained mainly from the northern Hills, is pre-eminently the chief mineral product, a total of one hundred million dollars having been obtained during the past twenty-six years. Silver has been of importance in the annual output, while other ores and minerals already productive, or capable of production, add much to the variety of the mining interests and not a little to the mineral wealth of the region.

GENERAL GEOLOGY.

The Black Hills region is one of peculiar geologic interest. Separated from the Rocky Mountains to the west and southwest by a distance of less than one hundred fifty miles, it possesses many of the features of that great uplift. By reason of its isolated position, the simple structural features of the region, and the many excellent rock exposures, its history may be interpreted with a considerable degree of ease.

The Hills are situated within the forks of the Cheyenne river, on the boundary line between South Dakota and Wyoming, a much larger portion being within the borders of South Dakota. Structurally the region is an elliptical quaquaversal uplift, the more distinct features of which cover an area about one hundred miles long and fifty miles wide, the longer axis approximately coinciding with the meridian, except in the northern portion, where the general direction is to the northwest.

The prominent topographic features are a high central basin of granite and metamorphic rocks of Algonkian age, surrounded in a concentric manner by a prominent infacing escarpment of massive white Carboniferous limestone, a wide depression in the red Triassic shales, and a high rim of Cretaceous hogback ridges or foothills. In the northern Hills post-Cretaceous intrusive rocks have greatly modified the general topography, and in not a few instances have formed prominent landmarks. Harney Peak, the culminating point of the Harney granite range, in the southern Hills, and the highest point within the uplift, reaches an altitude of 7,216 feet. The surrounding limestone escarpment rises high above much of the central portion and considerable areas of the plateau along the western side closely approach the height of Harney Peak. The mean altitude of the plains surrounding the Hills is little more than 3,000 feet. The average elevation within the hogback ridges is approximately 5,000 feet.

The rocks of the Black Hills show a wide range in age and character. Within the crystalline nucleus are pre-Cambrian granites, amphibolites, schists, slates, phyllites and quartzites. Beyond this nucleus are limestones, sandstones, shales and conglomerates, representing a nearly complete sequence from Cambrian to Laramie. Extensive overlaps of Tertiary deposits are also present. Silurian and Devonian rocks seem to be present in only a few localities, and are nowhere of importance. In the northern Hills there are porphyries, phonolites, dacites, tonalites and vogesites. The various sedimentary rocks have recently received careful study under the direction of the United States Geological Survey. The following section, by Mr. N. H. Darton, shows their age and general character.*

*Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming, U. S. Geol. Survey, Twenty-first Ann. Rept., Part IV, Hydrography, 1901, p. 503.

Generalized Section in the Black Hills Region.

Formation.	Character.	Average thickness.	Age.
Laramie.....	Massive sandstone and shale.	Feet. 2,500	Cretaceous.
Fox Hills.....	Sandstone and shale	250-500	Do.
Pierre shale.....	Dark gray shale.....	1,200	Do.
Niobrara.....	Chalk and calcareous shale.	225	Do.
Benton group: Carlile formation ...	Gray shales with thin sandstones, limestones and concretionary layers.	500-750	Do.
Greenhorn limestone	Impure slabby limestone.	50	Do.
Graneros shale.....	Dark shale with lenses of massive sandstone in its lower part at some places.	900	Do.
Dakota sandstone.....	Massive buff sandstone..	35-150	Do.
Fuson.....	Very fine-grained sandstone and massive shales. White to purple color.	30-100	Do.
Minnewaste limestone	Gray limestone.....	0-30	Do.
Lakota.....	Massive buff sandstone, with some intercalated shale.	200-350	Do.
Beulah shale.....	Pale grayish-green shale.	0-150	Jurass
Unkpapa sandstone...	Massive sandstone; white purple, red, buff.	0-250	Do.
Sundance.....	Dark drab shales and buff sandstone; massive red sandstone at base.	60-400	Do.
Spearfish.....	Red sandy shales with gypsum bed.	350-500	Triassic.
Minnekahta limestone	Thin-bedded gray limestone.	30-50	Permian.
Opeche.....	Red slabby sandstone and sandy shale.	90-130	Permian?

Generalized Section in the Black Hills District.—Continued.

Formation	Character.	Average thickness.	Age.
Minnelusa	Sandstones, mainly buff and red; in greater part calcareous. Some thin limestone included.	Feet. 400-450	Carboniferous.
Pahasapa limestone. . .	Massive, gray limestone.	250-500	Do.
Englewood limestone. .	Pink slabby limestone.	25	Do.
Deadwood	Red brown quartzite and sandstone, locally conglomeratic, partly massive	4-150	Cambrian.

In addition to the above named formations and to the pre-Cambrian and Tertiary rocks already mentioned, Pleistocene deposits of various kinds occur widely distributed over the surface of the region. Some of these, as well as certain of the older formations, on account of their economic interest, will be described more fully in subsequent pages.

The Black Hills region is drained by the Cheyenne river and its tributaries. Two main branches, the Belle Fourche and the South Fork, almost completely encircle the Hills and wholly isolate them from other systems of drainage. These encircling arms send radiating streams toward the more elevated portions of the uplift, the high western plateau being the main divide. It is of particular importance that, although the Black Hills are surrounded by a semi-arid plain, the Hills themselves have a considerable degree of rainfall and many of the streams within the more elevated portions flow without intermittence. The annual rainfall varies widely. Near the foothills, as observed at the United States weather station in Rapid City, it averages 16.71 inches. At Deadwood, situated further within the Hills, it is about 28.5 inches. This latter amount is perhaps a fair average for the areas in which the more extensive mining operations are carried on.

The probable geological history of the Hills is briefly as follows:.* In Algonkian time the schists and quartzites were de-

*Many authors have written on this subject. For the latest and most complete discussion of post-Algonkian conditions available at this writing the reader is referred to the following: Darton, N. H., Preliminary Description

posited as sediments derived from land lying apparently either to the west or to the northeast of the position now occupied by the Hills. Later these original sediments were cut by basic eruptives, at which time more or less metamorphism and folding were produced. Subsequent to this action the sedimentary rocks, as well as the basic eruptives, were ramified by quartz veins, many of which are gold-bearing. Following the eruption of the basic rocks, and after most or all of the gold-bearing quartz veins were formed, extensive granite intrusions occurred. Apparently at the time of the intrusion of the basic eruptives the slaty cleavage was produced, and approximately coincident with the granite intrusions the crystalline schists were developed. At some time during the middle or latter part of the Algonkian period the sea shallowed and the land rising above the sea as an island, reached a considerable height. The rocks thus brought under the influence of erosive agents supplied much or all of the sediments which make up the Cambrian strata.

Little is known of the conditions during Silurian and Devonian time, rocks of these periods being absent in the southern portion of the uplift and very scantily represented in the northern portion. Deep water prevailed during the early part of the Carboniferous period, and although the sea subsequently shallowed, apparently little or no land area existed near the region until after the period closed. The Triassic red beds, with their included widely distributed lenses of gypsum, following the extensive deposition of the nearly pure Permian limestone, indicate a considerable uplift and general shallowing of the sea. The shales, sandstones and impure limestones of the Jurassic show considerable oscillation and, on the whole, further shallowing of the sea. The Cretaceous rocks, including as they do a great series of diversified strata, represent several changes of conditions. In general it may be said that fairly shallow seas existed in the early and later portions of the period, while during much of the intervening time deep water prevailed.

Near the beginning of Tertiary time great disturbances took place. The region was lifted quite above the sea and deeply trenched by outflowing streams. Sea conditions disappeared, leaving the land partially or wholly surrounded by a considerable body of water in the form of a lake. Approximately coincident with these changes the post-Cretaceous igneous rocks of the north-

of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming. U. S. Geol. Survey, Twenty-first Ann. Rept., Part IV, Hydrography, 1901.

ern Hills were intruded among the sedimentaries, and by their subsequent denudation and degradation added their portion of sediment to the surrounding lake. The lake then disappeared and upon its dry bed the modern streams have trenched their way. Concerning this and subsequent activity, in view of the too frequent lack of appreciation of the work performed by streams, I cannot do better than quote from Prof. Newton. "The streams that had been transporting detritus from the Hills and casting it into the lake now found their way to the rivers and transferred their burdens to them. Little by little, but continuously, they have eaten away the substance of the Hills ever since. The canyons they have cut, and which appeal to our eyes as marvelous monuments of their industry, are the least of their results. Since their labor began they have demolished and removed one-half of the entire mass of the uplift. Modest and feeble as they seem, it is their ambition patiently to toil on until no vestige of the Hills remains."*

HISTORICAL REVIEW.

The existence of valuable gold deposits in the Black Hills was first made known to the world in 1875. Certain stories, still current, indicate that some of the Sioux Indians and a few white men knew of the presence of gold here several years prior to this time, but nothing definite can be learned as to the actual facts. The earliest authentic account of its finding dates from July 27, 1874, at which time Mr. H. N. Ross and Mr. W. T. McKay, miners accompanying the expedition of General Custer, found small quantities of the precious metal in the bed of French creek, in what is known as Custer park, the exact locality of the find being within the present town of Custer, between Washington and Custer avenues where crossed by Ninth street.† Plate 1 gives a view of the locality. In this view the exact place of discovery is shown to be some distance from the creek bed, the creek having been turned out of its former course by the railroad, which runs near. Owing to the rapid movements of the expedition no thorough prospecting could be done, and although gold was observed

*Report on the Geology and Resources of the Black Hills of Dakota, 1880, p. 222.

†Date and locality given by Mr. Ross, who now resides in Custer and by whom the old diggings were pointed out to the writer. In this connection see also the following: Ludlow, William. Report of a Reconnaissance of the Black Hills of Dakota, Made in the Summer of 1874. Wash., 1875, pp. 13 and 14.

in several localities no definite idea was gained as to the extent or value of the deposits.

The report that gold had been found, although greatly exaggerated, quickly aroused much excitement among the frontiersmen. As a result, only a few weeks after the Custer expedition, a party entering the Hills for the purpose of settlement reached French creek, and on December 23, 1874, the date of their arrival, found gold about three miles below the present site of Custer, near what is known in Black Hills history as The Stockade, a structure built by the party soon after their arrival for protection from Indians. The party did much prospecting in this vicinity during the winter, opening several quartz ledges within the park and sinking pits in the gravel bars along the streams, but were compelled by the military to leave the Hills early in the spring. Little gold had been found and the mineral wealth of the region still continued veiled in mystery.*

The Black Hills country was not then open to settlement, the area being at that time included within the reservation held by the Sioux Indians. The government made strenuous efforts to prevent prospectors from entering, and the Indians were continually upon the lookout for trespassers, but this seems only to have intensified the desire to explore and appropriate the country. As a result of this interest and as a possible solution of certain frontier difficulties, the government in the early part of the year 1875 organized a special survey for the purpose of learning definitely whether or not the mineral and other resources of the region were such as to warrant its purchase from the Indians for settlement. Professor Walter P. Jenney was appointed geologist in charge, with Mr. Henry Newton as associate geologist. The expedition reached the Hills in May, and shortly afterward established the fact beyond doubt that gold existed in the Hills in considerable quantity.

It is worthy of note that the first authentic published statement of the finding of gold in the Black Hills is given in a letter written by Professor Jenney to the Hon. E. P. Smith, Commissioner of Indian Affairs, Washington, D. C. The letter, dated Camp on French Creek, near Harney Peak, June 17, 1875, was first published in the Mining and Engineering Journal. It was included later in Professor Jenney's official report to the Com-

*Tallent, Annie D. *The Black Hills; or, The Last Hunting Ground of the Dakotahs*, 1899, p. 713.

missioner of Indian Affairs, published in 1876, and again in the Report on the Geology and Resources of the Black Hills, 1880.*

The gold to which Professor Jenney referred was found June 12, 1875, on the north bend of Castle creek, in terraces or bars of quartz gravel, and subsequently southward to French creek. Following this much prospecting of an unsatisfactory nature was done along French creek, but nearly a month later important discoveries northeast of Harney Peak, in the placer deposits of Spring and Rapid creeks, caused a rush in that direction, this being the first real stampede in connection with the Black Hills gold excitement. By this time several hundred prospectors had succeeded in gaining access to the region, and of this number more than one hundred staked out claims on Spring creek and proceeded to pan for gold.

Professor Jenney and his corps of miners continued their investigations throughout the summer, assisted in no little degree by the prospectors, who had entered the Hills contrary to the regulations governing the reservation. French creek and Castle creek received the most attention, although considerable prospecting was done along nearly all of the more important streams within the Hills. The work was carried on principally with reference to stream gravels, but observations were made also upon rock in place. The results of these observations indicated no rich deposits, such as have since been the cause of so much interest and excitement in the region, but were such as to give promise of good returns for careful work in many parts of the Hills.

The fact being therefore established that the Black Hills region was of much greater value for mining purposes than it could ever be to the Indians, the government at once entered into negotiations for the purchase of this part of the reservation. The negotiations were for a time unsuccessful, the Sioux war intervening, but the transfer was finally accomplished and the region was opened for legal settlement February 28, 1877. The Indians received the purchase price of four and one-half million dollars. Prior to the date of the President's proclamation permitting settlement and the legal holding of land, proper titles could not be acquired, but under such arrangements as miners find it necessary to adopt in new countries, claims were laid out, controlled and worked. Owing to the practical impossibility of

*Report on the Geology and Resources of the Black Hills of Dakota with Atlas. By Henry Newton, E. M., and Walter P. Jenney, E. M., 1880, p. 566.

preventing the entrance of prospectors, the government in the latter part of 1875 withdrew all opposition to immigration to the Hills, and at the same time began to withhold much of its protection. As a result, Indian depredations became frequent, and lawlessness and disorder were common. People, eager to gain some of the reported fabulous wealth, continued to hurry to the region, so that before the President's proclamation was issued a number of mining camps and towns had been established and the aggregate population had reached several thousand.

In the fall of 1875 a small party from the southern portion of the Hills prospected northward along the headwaters of various streams and reaching Deadwood gulch, in the northern Hills, in November, located what is known as Discovery claim, a little below the mouth of Blacktail gulch. Some indifferent prospecting had been done in this vicinity during the preceding August, but it was not until near the close of December that rich deposits were found. Prospecting was continued during the winter months in this and neighboring gulches in what is now known as Lawrence county, and in the spring extremely profitable placer mining began. Previous to this time incoming parties had made Custer park, in the southern Hills, their first objective point, but with the discovery of the rich placers of the Deadwood region the northern Hills at once gained supremacy. The discovery a few weeks later of the rich conglomerate ores and of the great impregnated zone known as the Homestake belt indicated the permanent wealth of that part of the Hills, and during each of the twenty-six years since that time Lawrence county alone has far surpassed all the remainder of the Hills in the production of gold.

Other facts in connection with the history of the region are of interest, but for these the reader is referred to subsequent pages in which the development of the various deposits is reviewed. One feature, however, in the advancement of the region needs to be mentioned here, namely, the construction of railroads.

For ten years after the discovery of gold the Black Hills had no railway facilities of any kind. Mills were freighted long distances, generally from Bismarck, North Dakota; Cheyenne, Wyoming; or Sydney, Nebraska, and such ore as demanded treatment outside of the Hills had to bear the expense of similar haulage.

In November, 1885, the Fremont, Elkhorn and Missouri Val-

ley railway, of the Northwestern system, reached Buffalo Gap, near the southern edge of the Hills. In December, 1890, it entered Deadwood. Five weeks later the Burlington railway also entered Deadwood, and thus healthy competition in ore transportation began. A little before this, in 1890, the interurban narrow gauge line connecting Deadwood and Lead was constructed and put in operation. Much of the Black Hills and Fort Pierre narrow gauge road, connecting Lead and Piedmont, had been built earlier, but it was constructed for the particular convenience of the Homestake company, and for several years its chief use was in the transportation of timber and fuel from the forest to the mines. In 1901 this road was purchased by the Burlington.

Soon after reaching Deadwood the Fremont, Elkhorn and Missouri Valley, and the Burlington, extended branch lines to the mines near Ruby basin, Bald mountain, Portland and Crown Hill, the Burlington descending into the picturesque Spearfish canyon and going on to Spearfish. At this writing the two roads are extending their main lines into Lead, and the Burlington is entering Galena. Thus the northern Hills are favored with excellent railway facilities, and to this fact is largely due the opening up of many important mines. The central and southern Hills are not so well supplied, but the construction of a branch line to Keystone by the Burlington three years ago, from its main line at Hill City, has partially relieved the demand.

MINERAL PRODUCTS.

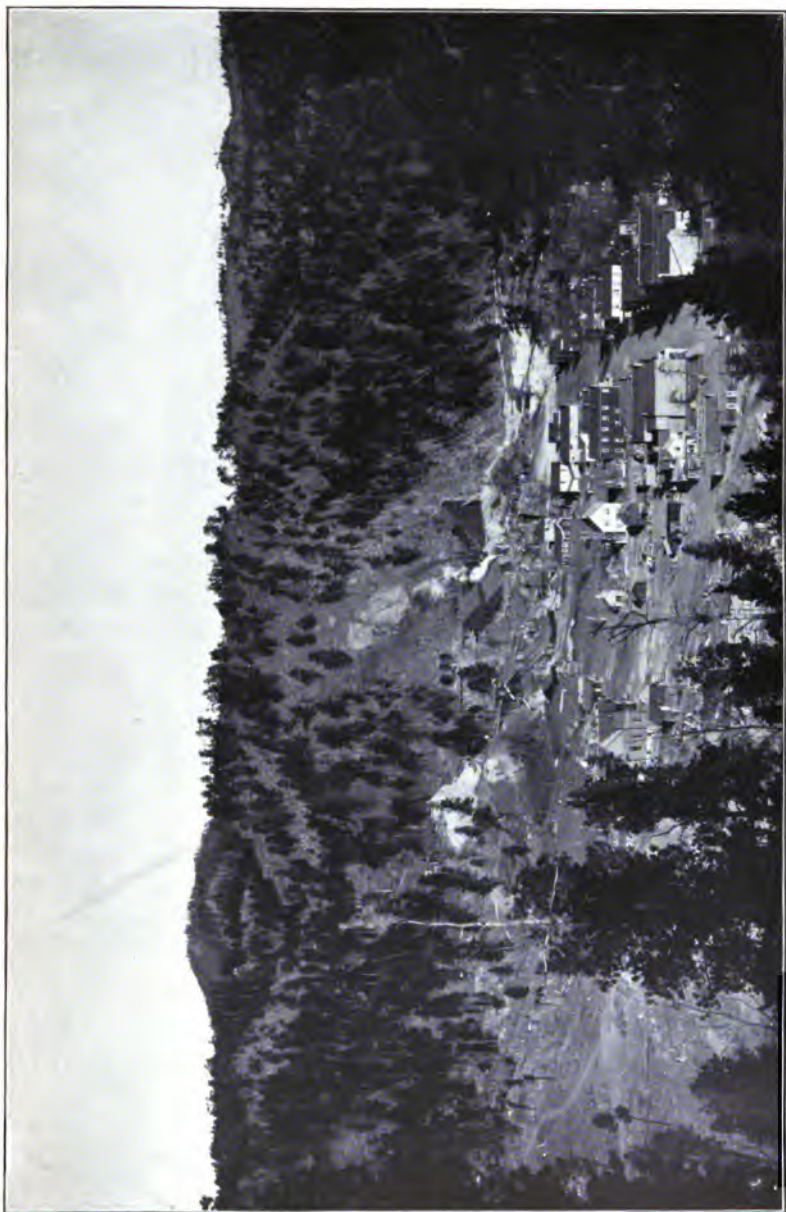
The mineral products discussed in this paper may be conveniently arranged as follows:

Metallic:	Non-Metallic:
Gold,	Graphite,
Copper,	Mica,
Iron,	Spodumene,
Manganese,	
Silver and Lead,	Miscellaneous.
Tin,	
Tungsten.	

Of these, the metallic products will be treated first. The members of each group follow one another in alphabetical order, with the exception of gold, which, by reason of its enormously greater importance, is given first.

GOLD.

Classification of Black Hills gold ores:



PHOTOGRAPH BY CROSS, 1900.

THE HOLY TERROR AND KEYSTONE MINES, KEYSTONE.

The Keystone mill in the rear on the right, the Holy Terror hoist above on the left.

c

- A. Ores occurring within the Algonkian rocks.
 - 1. In quartz veins.
 - 2. In veins of auriferous pyrite.
 - 3. In igneous dikes, sheets, etcetera.
 - 4. In slate breccias.
 - 5. In fissure veins.
 - 6. In mineralized zones.
- B. Ores occurring within the Cambrian rocks.
 - 7. In the basal conglomerate—"cement ores."
 - 8. In the slates, sandstones and quartzites—"siliceous" ores.
- C. Ores occurring within the Carboniferous rocks.
 - 9. In brecciated "verticals" in limestone—"siliceous" ores.
 - 10. In massive limestone—"lime-siliceous" ores.
- D. Ores occurring within the Pleistocene deposits.
 - 11. In high level bars—"dry" placers.
 - 12. In present stream beds—"wet" placers.

In the treatment of the above divisions numbers 3, 4 and 5 are discussed together, likewise numbers 9 and 10, and numbers 11 and 12.

THE VEIN QUARTZ ORES.

The gold-bearing quartz veins are found chiefly in the central and southern Hills in Pennington and Custer counties. Lawrence county, in the northern Hills, includes some valuable quartz veins, but thus far few of these have been extensively developed.

The first prospecting on the quartz veins was done in Custer county in 1875. The first ton of gold-bearing quartz subjected to careful treatment was taken in August, 1875, by Joseph Reynolds from a ledge near French creek, about three and one-half miles above Custer, and sent by wagon and team, at a cost of forty-five dollars, to Cheyenne, Wyoming, where it was sampled and sent to Georgetown, Colorado. Some of the ore was found to run as high as seventeen dollars a ton.*

The first claim to be worked extensively was the Grand Junction, located seven and one-half miles northwest of Custer, near the Custer-Pennington county line. The claim was staked in April, 1879, and in 1880 a twenty stamp mill was erected.

*Tallent, Annie D. The Black Hills; or The Last Hunting Ground of the Dakotahs. St. Louis, 1899, p. 165.

This mill ran intermittently until 1882, during which year twenty more stamps were put in. The enlarged mill ran until 1885, when the ore, which had been chiefly free-milling near the surface, became too refractory for amalgamation, and work was suspended.

Among other properties early located are the Atlantic, the Old Bill, the Old Charlie, the North Star, and the May Flower, near Custer; the King Solomon and the Grizzly Bear, near Hill City; and the Montana, near Rochford. Mills have been erected on some of these properties, all of the mines have been intermittently productive and most of them have afforded some rich ore.

Many properties have recently become of importance, and several of the older abandoned mines are again receiving attention. Of the present active mines the Holy Terror, of Pennington county, plate 2, and the Uncle Sam, of Lawrence county, plate 3, are the chief producers

Quartz veins are abundant throughout the area occupied by the Algonkian metamorphic rocks. They generally, but do not always, follow the foliation of the slates, schists and quartzites, with which they occur, and the individual vein may occasionally be traced a considerable distance. As frequently observed elsewhere, they show great variation in thickness, especially in the schistose areas, where the veins are often of lenticular form, and where in the more extensive veins swelling and narrowing seem to be the rule rather than the exception. The thickness seldom reaches fifty feet, and in most cases it is very much less than this, much of the mining and exploratory work having been carried on along veins less than four feet in thickness. The veins seem to be more numerous in the schists than in the slates, but the veins in the slates are in general said to be thicker, more clearly defined, and more persistent than those found in the schists.

Professor Newton refers to the veins as "veins of intercalation," and states that some of them appear to be "true veins," formed by the collection of quartz along lines of separation of the strata. Professor Jenney in much the same way states that they are not "true fissure veins," but designates them as "inter-laminated fissure veins," and adds that the veins are chemical precipitations from water holding silica in solution, partly, at least, derived from the wall rocks of the veins, and undoubtedly formed during the folding of the strata, at which time the gold must also have been deposited. In this connection it should be

borne in mind that the foliation, which has been interpreted by some investigators of Black Hills geology as largely or wholly coincident with original stratification planes, has been shown by Professor Van Hise to be chiefly due to metamorphic processes which have practically obliterated the stratification planes, except in favored localities, where with careful study the original relations may be discerned.

The veins have a general north-south trend, sometimes swaying considerably to the east or west. Such veins are locally known as "formational veins." Occasionally cross veins are found which follow fractures at a considerable angle to the foliation, not infrequently being approximately at right angles to the general trend of the formational veins. These cross veins, like the north-south veins, may be gold-bearing, and in some cases are said to be quite rich.

The quartz of which the veins are composed is highly crystalline, and is generally opaque white. When auriferous it is often bright and translucent, with not infrequently a bluish or black tinge. Iron oxide, in the form of limonite, commonly occurs, intimately associated with the quartz near the surface and occasionally in considerable quantity. Pyrite is an associate, but is found only in the deeper workings. On the Chilkoot and neighboring properties, eight miles east of Custer, crystallized graphite is found filling minute cavities in the quartz. Tetradyomite is found as an associate on the Newark property near Custer.* Siderite is common in many places, particularly in the vicinity of Rochford. Galena is common in the Uncle Sam mine at Perry, plate 3, particularly in connection with the richer pockets of gold, and sphalerite is not an infrequent associate. Other mineral associations doubtless occur, but apparently little attention has been given to their observation.

The gold in all of the developed properties is more or less free-milling, as may be readily seen by the ordinary pan test. It is almost completely free near the surface, but becomes gradually more and more refractory with depth. For some reason not yet clearly explained the concentrates at many of the mines have not yielded readily to metallurgical processes, and largely for this reason a number of apparently valuable properties are now idle. The Holy Terror mine at Keystone, plate 2, which is down 1,200

*Smith, F. C. Notes on Black Hills Geology, Black Hills Mining Review, Sept. 3, 1900.

feet vertical, has perhaps had the longest approximately continuous run of all the mines on vein quartz. In this mine the free gold has continued in abundance with depth, but even here, and especially in that portion of it formerly known as the Keystone mine, the concentrates are important. The refractory ores from various mines are now being experimented upon and doubtless a satisfactory method of treatment will be found.

One feature of interest in development work within the granite area is that the granite is younger than the auriferous veins, and since it often protrudes into the metamorphic rocks in the form of dikes, sheets and irregular masses must necessarily cut such auriferous quartz veins as may have originally intersected its pathway. In many such cases the displacement is not great, and by going through the granite flow the vein may be again encountered without great expense. This has been done in a number of instances, particularly in the Chilkoot district.

The gold occurs generally in minute particles scattered through the quartz, but many properties have afforded excellent display specimens. The value of the workable veins varies widely. Twenty dollar ore is common, fifty dollar ore is not infrequent, and much higher assays are occasionally observed. The Holy Terror mine, until recent litigation hindered its development, showed phenomenally rich ore for many weeks in succession, and the statement is made that by means of a ten-stamp mill it has produced as high as \$70,000 in one week. The vein is narrow, and sinking has consequently progressed rapidly, the vertical shaft being now down 1200 feet.

The rather checkered career of many of the mines on quartz veins has greatly handicapped the study of these deposits. Unwise management and difficult conditions have too often combined to render efforts unsuccessful which apparently should have gained excellent returns. Recently there has been improvement in many ways. Perhaps never before has there been so much development work done on quartz veins during the same length of time as during the last twelve months. Gold exists in these veins in quantity, and although presenting difficulties often not easily overcome, they will doubtless rise in the future to a much more commanding place than they now hold.

AURIFEROUS PYRITE VEINS.

No veins of pyrite in the Hills are worked exclusively for their gold content. Pyrite veins in various parts of the Hills have received attention in past years, but at present, so far as I



PHOTOGRAPH BY O'HARRA, 1901.

THE UNCLE SAM MINE, HOIST, AND MILL, AT PERRY.

can learn, only three properties are producing ore, and these produce only for fluxing purposes. These are the Slavonian mine, near Lead, and the Gilmore and the Seim mines, near Deadwood. The Bion, near Galena, contains a wide vein, but is not producing. Other properties could doubtless furnish much material were railroads convenient and smelter demands sufficient. All of the ore now produced is sold to the Golden Reward smelter at Deadwood for use as flux in the reduction of the Cambrian siliceous ores, the value of the pyrite depending somewhat upon its purity and the amount of gold and copper present. The pyrite from the mines mentioned is said to carry from fifty cents to three dollars a ton in gold, and generally a small per cent of copper, the latter occasionally running up to three or four per cent or more. Silica is generally present in greater or less amount, and the per cent of graphite is occasionally high.

The Seim mine has been worked since 1890 and the Slavonia for a considerable time. The Gilmore mine has just begun producing. No account of the total output is at hand, but the present production of the mines is from fifty to one hundred tons a day.

AURIFEROUS DIKES, SLATE BRECCIAS AND FISSURE VEINS

The porphyritic rocks of the northern Hills, as well as the dioritic and granitic rocks of the central and southern Hills, are occasionally auriferous, but with some few exceptions little economic importance has been attached to them. In Pennington and Custer counties the dioritic schists have been exploited with some confidence, but as yet none of the properties have become strong producers. The porphyries near Galena are of considerable geological importance and occur in the form of dikes and sheets. Gold is widely diffused through these rocks, it being found both in the dikes and in the sheets, generally with iron pyrites, but sometimes free.

Interesting slate breccias and fissure veins also occur in the Galena district. Having had no opportunity to examine these, I quote from Professor Jenney, who has studied them and who describes them as follows: "Broad zones or belts of gold-bearing breccias traverse the schists and slates in the Union Hill, Hoodoo and adjacent mines. These breccias are made up of angular fragments of slate, a confused mass of material without any apparent order of arrangement; the pieces of slate of all sizes and shapes cemented together into a solid rock. Among the

rock fragments may be found siliceous slates, mica slates and schists commonly occurring in the vicinity, with less frequently quartz derived from the older veins. The slate fragments are more or less decomposed, softened and bleached in color, probably owing to the action of heated alkaline waters during the mineralization. The porphyry intrusions in the breccias are locally kaolinized; quartz alone has resisted alteration. In some localities the breccias are formed of dike-like masses of porphyry, through which the fragments of slate are irregularly distributed, evidently having been inclosed in the fluid igneous rock at the time of the intrusion. In other places porphyry is absent and the breccias are entirely composed of material resulting from the crushing and alteration of the primary rocks. These distinctions are not well defined; every gradation in the character of these fragmental rocks is seen in the district. Dikes and intruded masses of porphyry with only scattered inclusions of slate, gradually merge, from an increase in the relative proportion of inclosed fragments, into breccias largely made up of slate. Iron pyrite containing gold is disseminated throughout the breccias in varying amount. The pyrite is mainly deposited in the cementing material, though the slate fragments have a little disseminated mineral. The gold, together with the pyrite, is readily separated from the ore by concentration; a small part of the gold is free in certain ore deposits and can be amalgamated. Near the surface the ores are oxidized and a somewhat larger proportion of the gold is free. These ore deposits are of great extent; a breccia developed in the Hoodoo mine is more than 200 feet in width, and of unknown length on its course. Similar ore bodies occur in the adjoining mines and can be traced on the surface for distances of 1000 to 2000 feet. The origin of these breccia deposits appears to have been due to crushing of beds of slate by movements of the strata, caused by the intrusion of the igneous rocks; the mineralization taking place at a subsequent period.

"Fissure veins traverse the slates, locally extending up into the porphyry overflow. The veins are commonly narrow and frequently carry high grade ore. A vein of this type lately opened in the Hoodoo mine is six feet in width; the ore slate and quartz carrying pyrite and free gold. Narrow veins filled with decomposed porphyry, bearing gold and often high grade, occur in the porphyry overflow covering the surface of Union Hill; certain vertical fissures carry ores of copper."*

*Report on the Geology and Ore Formation of the Black Hills, Black Hills Mining Review, March 21, 1898, pp. 11 and 12.

IMPREGNATED ZONES.

The ores of the impregnated zones are of great importance. One of these zones, known as the Homestake Belt, has furnished approximately three-fourths of the total gold output of the Black Hills, and notwithstanding the recent rapid advancement in the utilization of other varieties of ore, this belt is now affording more than one-half the annual output.

Thus far the ores of the impregnated zones have been continuously worked for a considerable length of time only in Lawrence county. Many claims, however, in Custer and Pennington counties are said to carry as high values as the Homestake ore, and some of the ore bodies in these counties are large.

Of the properties outside the Homestake belt that have been worked, perhaps none have been more extensively exploited than the Standby at Rochford. This mine was opened in the early years of Black Hills history, and although worked intermittently, has been a producer of no mean consequence. In the past only the free-milling gold was saved, no effort being made to secure the refractory values. At present substantial exploratory work is being done on lower levels than before, and efforts will be made to save such concentrates as may be found. The Bullion and other mines near Keystone have furnished considerable gold, but these are not now producing. In the Hornblende district west of Rochford several mines are being developed, but none have reached the stage of steady production. Custer county also has various properties of a similar nature, but none are active producers. In several of the properties coming under the class of impregnated zones, the gold is practically all free-milling at the surface, while in others it is only partly free-milling or mostly refractory. Several years ago Professor Carpenter, while Dean of the School of Mines, tested some of the more refractory ores and made calculations as to their probable value if mined and treated carefully on a large scale, such as is done by the Homestake company. It is sufficient here to state that in several instances favorable results were reached.*

The Homestake mine, widely known as the greatest low grade gold mine in the world, is the typical example of the class, and having been an important factor in the development of the Black Hills, may be described in some detail.

The mine lies to the southwest of Deadwood, being situated

*The Mineral Resources of the Black Hills. Preliminary Report of the Dakota School of Mines, 1888, pp. 118-121.

between Whitewood creek and Deadwood gulch. Near the mine and at equal pace with its development a busy town, Lead (pronounced Leed), has grown up, the town now the largest in the Black Hills, plate 5, taking its name from the miners' term "lead," meaning lode.

The first claims located on property now controlled by the company were the Giant and the Old Abe. These were located by J. B. Pearson, December 11, 1875, and, aside from placer claims, are believed to have been the earliest mineral locations in the Hills. Early in 1876 the Homestake, the Highland, and the Golden Star were located, and the Old Abe, which had been previously abandoned, was relocated. During this year the owners of the Homestake claim prosecuted vigorous development work and constructed and operated a crude arrastre, with which they obtained excellent results.

In 1877 two stamp mills were utilized in treating the "belt" ores. The first, a ten-stamp mill, later increased to twenty stamps, was erected by the Racine Mining and Milling Company, the mill arriving at Lead April 7th. The stamps began dropping April 15th and the first clean up was made April 20th. The second mill, erected by Mr. Enos, who had purchased a considerable portion of the Homestake claim, was put in operation in July. Subsequently, when the Homestake company acquired the properties from which these mills had obtained their ore supply, the mills were torn down and the machinery removed to other localities.

The Homestake Mining Company was incorporated November 5, 1877, but its real history began several months prior to that time. In the fall of 1876 Mr. L. D. Kellogg, a representative of Mr. J. B. Haggin, and Senator George Hearst, of California, arrived in the Hills and made a preliminary examination of various properties in the vicinity of Lead. In January, 1877, Mr. Samuel McMasters visited the locality under the direction of the same individuals, and during the summer and fall a thorough examination was made. Senator Hearst then personally inspected the properties, purchased various claims, and arranged immediately for the erection of an eighty-stamp mill. The mill was shipped by rail to Sydney, Nebraska, from which point it was freighted to the mine by ox team, the cost of transportation from Sydney to Lead amounting, it is said, to \$33,000.

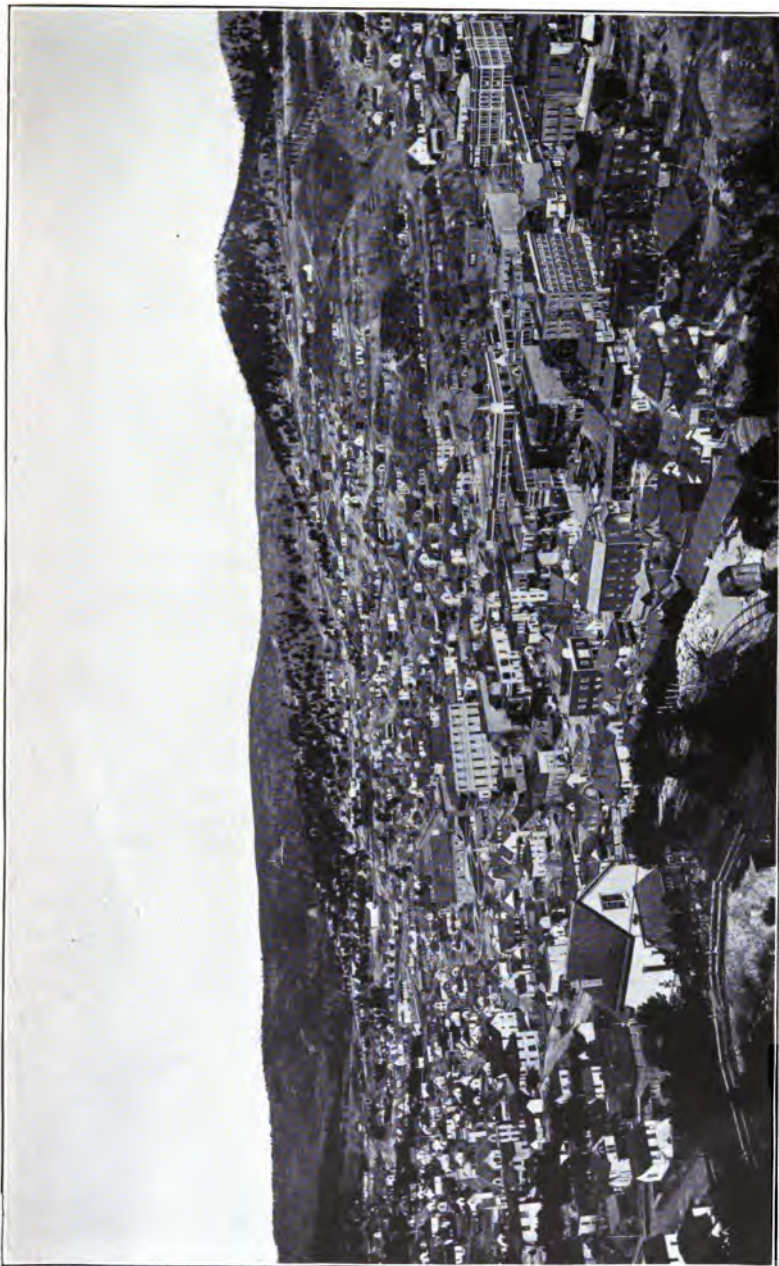
In July, 1878, during which month the eighty stamps were placed in commission, the first and only assessment in the his-



PHOTOGRAPH BY O'HARRA, 1901.

PART OF ONE OF THE HOMESTAKE OPEN CUTS, LEAD.

Porphyry above the railroad; mostly slates and schists below. "V" shaped portion on the left contains porphyry and quartzite and is enlarged in plate No. 9.



PHOTOGRAPH BY CROSS, 1901.

LEAD CITY.

The Homestake mine and mills join this view on the right.

tory of the company was levied. This was at the rate of one dollar a share and afforded \$200,000 required for the erection of the mill.

As the magnitude of the ore deposit became more clearly defined by exploratory work the milling capacity was increased, important timber and water rights were acquired, a short, but important, railway line was constructed, and absorption of various companies controlling adjoining properties was brought about. Some idea of the company's present surface equipment can be gained by reference to plate 15, in which there is shown a view of the hoists, mills, etcetera, near Lead. This does not include the 1300-ton cyanide plant recently constructed below Lead, the 700-ton cyanide plant now building at Central, nor the hoists and stamp mills at Terraville and Central.

In general the mine has shown a steady growth in production and most of the mills have been running continuously. Within two years after the installation of the original Homestake eighty-stamp mill a total of five hundred eighty stamps were dropping. These were distributed as follows: The Homestake at Lead, erected 1878; eighty stamps; the Father De Smet at Central, erected 1878, eighty stamps; the Golden Star at Lead, erected 1879, one hundred twenty stamps; the Deadwood at Terraville, erected 1879, sixty stamps; the Caledonia at Terraville, erected 1879, sixty stamps; the Golden-Terra at Terraville, erected 1880, sixty stamps; and the Highland at Lead, erected 1880, one hundred twenty stamps.

All of these mills continued in active operation until 1892, at which time the Father DeSmet ceased and in 1893 the Caledonia followed. This action was necessitated by the scarcity of water and by the low tenor of the free-milling ore in these mines. About this time, however, the Homestake mill increased its capacity by the addition of twenty stamps, the Golden Star by the addition of forty stamps, and the Highland by the addition of twenty stamps.

In 1899 a largely increased supply of water was obtained from Spearfish creek, and in 1900 a 1300-ton cyanide plant for the treatment of concentrates was completed. At present all of the mills are in active operation, the total number of stamps dropping being 900, distributed as follows: The Homestake, 200; the Golden Star, 200; the Highland, 140; the Deadwood-Terra, 160; the Caledonia, 100; the Father DeSmet, 100.

The ore-bearing area of the Homestake belt as definitely ex-

ploited covers an area approximately one and one-half miles long and one-half mile wide. Two active companies are now carrying on extensive exploratory work outside of this area, the Hidden Fortune Company to the north of Lead, and the Black Hills Development Company to the south, in the belief that the ore bodies may be found beyond the boundaries as generally defined.

The ore lies in lenticular bodies of great extent, the workable portions in some places exceeding 400 feet. In one place it is said to reach 525 feet. By reason of this great width much of the ore has been worked by open cuts, some of which cuts have grown to great size, as shown in plates 4 and 15. At present most of the mining is underground. The deepest working levels are 1100 feet below the surface. The ore bodies have practically the same foliation as the surrounding country rock, the general strike, according to Dr. Carpenter, being $N\ 37\frac{3}{4}^{\circ}\ W$ and the dip steeply to the east. Amphibolites and porphyries are present. The amphibolites conform closely to the foliation of the enclosing metamorphic rocks, while the porphyries, sometimes in dikes and sometimes in sheets, either stand approximately parallel to the foliation, or lie across the uneven edges of the upturned rocks.

The gold occurs chiefly in chloritic and amphibole schists highly impregnated with quartz. The principal associate minerals are iron pyrite, pyrrhotite, and arsenopyrite. Ore highly charged with iron pyrite generally falls below the average value in gold, while the arsenopyrite ore is more often above the average. In the surface workings iron oxide is abundant, and the color of much of the ore is reddish brown. On the lower levels, where the unchanged sulphides abound and where the quartz is clear and the schists are fresh, the general color is green.

The free-milling character of the ore is pronounced. Practically all of the values in the surface ores are extracted by simple amalgamation. During the first twelve years of mining operations no attempt was made to save concentrates, although the deeper ores gradually became less free-milling. Concentrates have been saved since 1890. Until two years ago they were sent to the smelter at Deadwood for treatment, but in 1900 the company erected a 1300-ton cyanide plant at Lead, which is now successfully treating the tailings by the cyanide process. The company, having proven to its satisfaction that the cyanide process can be used advantageously, has recently begun the

erection of a second plant of 700 tons capacity, the location of this plant being at Central.

The sulphides vary generally from three to five per cent of the ore, but occasionally run up to ten per cent or higher. The assay value of the concentrates, of which about 85 per cent is iron sulphide, averages \$7 a ton. The present average value of the gold in the ore is usually given at about \$4.50 a ton, of which approximately \$3.50 is saved. The new cyanide plant will materially lessen the waste.

Concerning the origin of the ores, Dr. Carpenter suggests, that at the time of deposition of the enclosing rocks, large quantities of proto-sulphide of iron were formed through the agency of decaying organic matter whose presence at that time is attested by the large quantities of graphite now found in these beds. Originally this proto-sulphide was practically free of gold but later by the action of ferric salts in solution the proto-sulphide was changed to bi-sulphide, and the iron solutions which wrought the change also brought the gold which is now found in these deposits. The intrusion of the porphyry he thinks has been beneficial for two reasons: First, it has rendered the ores more free-milling. Second, it has in its neighborhood produced either an enrichment of the deposit or a further concentration of what gold originally existed in it.*

In view of the fact that the Hills were the seat of much igneous activity previous to the metamorphism of the Algonkian series, as indicated by the widespread distribution of basic rocks now represented by the amphibolites, and further that the auriferous quartz veins were formed prior to the granite intrusion which took place during algonkian time it seems possible that the amphibolites may have caused or controlled the original deposition of much of the gold now found in the impregnated zones.

In the absence of careful investigation it is difficult to say whether or not the amphibolites did exert any controlling influence, but their present relation to the metamorphic sedimentaries suggests that they may have been forced into the Algonkian sedimentary rocks in much the same way that the post-cretaceous eruptives have been injected among the Cambrian and Carboniferous rocks. This being the case subsequent mineralization

*Preliminary report of the Dakota School of Mines, Rapid City, 1888, pp. 113-115.

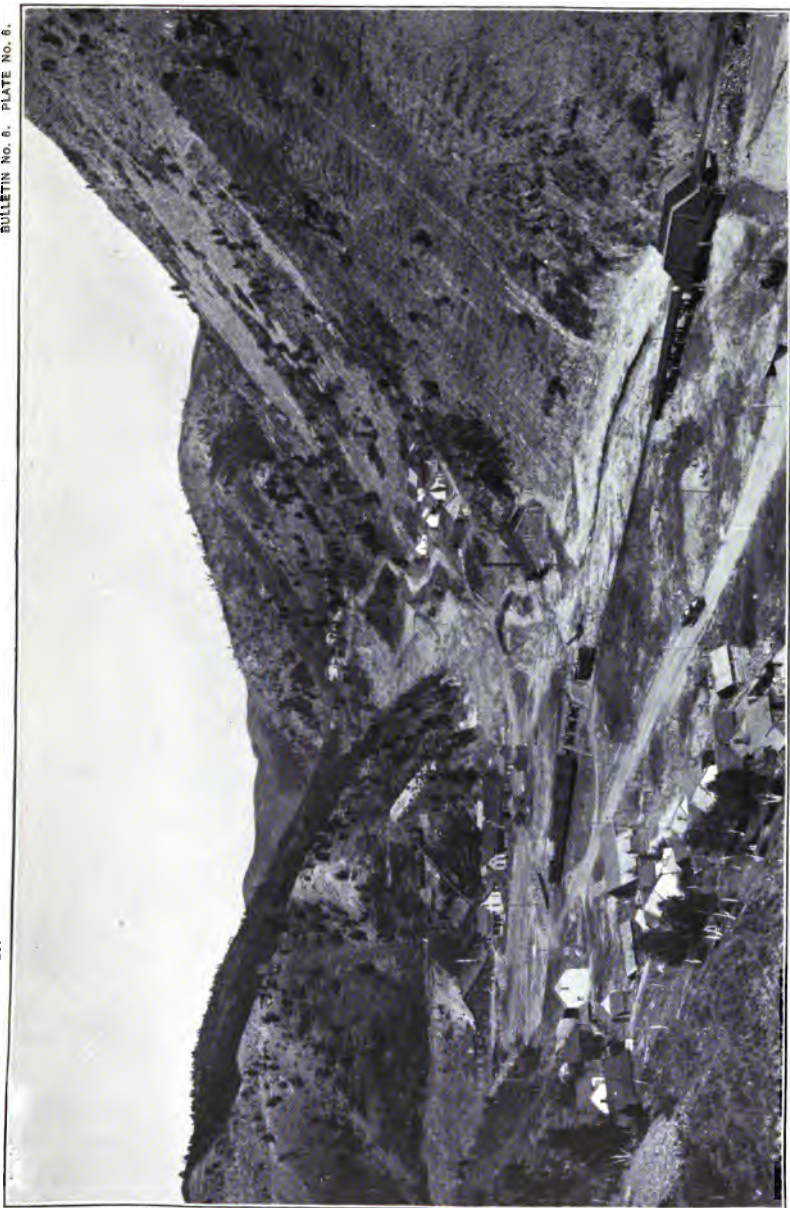
may have taken place in some way not greatly different from that which has been brought about in the northern Hills since Cretaceous time, the chief difference being that in the former the final processes left the gold in veins and in impregnated zones in a partially or wholly free milling condition, while in the latter it is in the form of ore shoots and is quite refractory.

CEMENT ORES.

The auriferous character of the Cambrian conglomerate within the porphyry capped hills to the west and southwest of Deadwood was discovered in the early part of 1876 only a little later than the finding of the rich placers in Deadwood gulch. Owing to the occasional high values which the ores contained and the ease with which the gold could be extracted, it being chiefly free-milling in the richer portions, the discovery led to immediate and pronounced excitement. For several months only the crude arrastre could be utilized in milling the ores, the first one having been constructed by Gardner, Chase and Company, owners of the Chief of the Hills, but these were efficient enough to indicate the profit with which the ore could be worked, and better mills were rapidly brought in to replace the hastily constructed makeshifts.

The first quartz mill brought into the Hills reached Deadwood September 25, 1876, and was placed a short distance above Gayville on Deadwood gulch. This pioneer quartz mill of the Black Hills consisted of a Blake crusher and a Bolthoff ball pulverizer arranged for steam power and was brought to the Hills by Captain C. V. Gardner. The mill treated the rich conglomerate ore from the Hidden Treasure mine on Spring gulch, the claim having been located May 13, 1876, and before the close of the year had produced twenty thousand dollars in gold. A little later Milton E. Pinney brought in the first stamp mill. This was a ten-stamp plant and was erected on the Alpha-Omega property near Central. This mill, as in the case of the Gardner mill, was purchased at Central, Colorado, and shipped by rail to Cheyenne, Wyoming, from which latter point it reached its destination by means of heavy freight wagons. The expense of hauling from Cheyenne was twelve and one-half cents a pound. The mill began dropping its ten stamps December, 30, 1876, and quickly proved a profitable investment.

Mills rapidly multiplied until the early part of the year 1878, at which time the milling of conglomerate ores was at its height.



PHOTOGRAPH BY O'HARRA, 1901.

BLACKTAIL GULCH, GAYVILLE IN THE FOREGROUND.

About twenty mills were in active operation, dropping approximately five hundred stamps. After 1878 the richer deposits gradually became exhausted, and by 1881 work upon them had practically ceased. However, as in the case of the placer deposits, a few properties have continued to be worked in a small and intermittent way even to the present time. Recent developments in metallurgical methods seem to indicate the possibility of these ores being utilized to considerable profit in the future owing to the fact that much of the ore contains refractory gold along with the free gold. Several companies are now studying the problems involved.

The conglomerate is at the base of the Cambrian rocks, known as the Deadwood formation as developed in the Black Hills, the series here representing apparently only the middle Cambrian, hence not properly called Potsdam as was formerly supposed, and lies unconformably upon the highly metamorphosed and upturned Algonkian rocks. The conglomerate is made up of well-rounded and sub-angular boulders and pebbles of quartz, slate, schist, etcetera derived from the Algonkian rocks on which it rests. In the Deadwood locality pebbles of hematite are frequent. The ore is tightly cemented by iron oxide and silica with some lime, and generally requires blasting in mining and the stamp mill for crushing. It is this character which gave it the name "cement ore" by which it is generally known within the Hills. Two classes of ore are recognized, namely, the oxidized and the unoxidized. The oxidized ore is deep brownish red, due to the iron oxide present, while the unoxidized is more of a grayish color, fresh looking, and contains considerable iron pyrite.

The conglomerate varies in character, being usually a single thick bed, sometimes in two or three separate beds, and occasionally is wholly wanting. In general it merges gradually above into coarse-grained sandstone or, where locally changed, into quartzite. It is found throughout a large part of the Hills where the proper horizon is disclosed, but in no place distant from the Deadwood locality has the gold been observed in remunerative quantities. The only other locality where there has been a worthy effort to work the deposits is at Gold Hill, near Rockerville, at which place a ten-stamp mill was in operation several months during the year 1878 but the results were unsatisfactory and the work was abandoned. The formation dips gently toward the outer rim of the Hills and the ore is readily reached

by lateral drifting. The areas which have produced the gold lie mostly to the east of the Homestake belt within a distance of one mile from the belt, the ridge between Deadwood gulch and Bob-tail gulch being especially productive.

Mr. Walter B. Devereux, from whose paper* the writer has obtained much of the information concerning these ores, states that the productive material includes only a few feet of the lowest part of the conglomerate, and, like ordinary placer deposits, shows pay and lean streaks and the occurrence of most of the gold near bed rock. The gold moreover has the characteristics of placer gold, and in every respect the similarity between these deposits and recent placers is so prominent that Devereux gave them the name "fossil placers," a name by which they have since been frequently called. The Homestake belt, now intersected and partially covered by post-Cretaceous eruptives, was evidently the immediate source of much of the gold, the belt having served as the shore line in this locality, while the heterogeneous materials of the conglomerate were being deposited in the shallow waters of the primordial sea. The relative positions of the Homestake belt, the Cambrian strata containing the cement deposits, the capping porphyry and the recent placers along the present stream valleys as indicated by Mr. Devereux are all shown in figure 1.

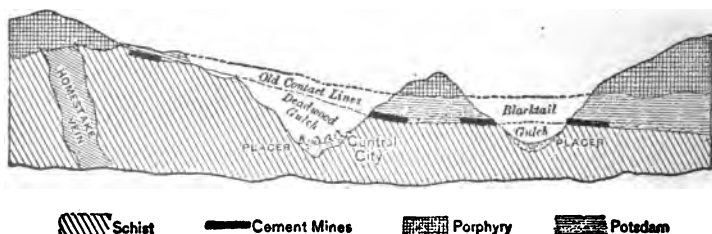


Figure 1—Approximate Geological Sketch through Homestake Vein.

Devereux discusses at some length the immediate source of the gold, referring chiefly to the free-milling gold, and the method of its concentration, giving facts to show that a small portion of it has been deposited through chemical solution, but that the great locating cause has been the high specific gravity of the gold; in short that the general conditions have been those of ordinary placer deposition. This idea has long prevailed, but it

*The Occurrence of Gold in the Potsdam Formation, Black Hills, Dakota, Am. Inst. Min. Eng., Trans. Vol. X. pp. 465-475.

is possible that the post-Cretaceous eruptives may have influenced the concentration more than Devereux was led to believe.

In view of the fact that the Homestake belt has been considered as the chief source of the gold, at least of the free-milling gold, it is interesting to note that certain comparative analyses of the metal lead to the same conclusion. Silver being more soluble than gold, it would seem that the cement gold should be purer than that from the Homestake belt, the silver percentage being lowered during the process of disintegration and concentration, and further that the finer the particles of cement gold the greater degree of purity it should have. The following analyses show this condition.*

	I	II	III	IV	
	Coarse gold	Coarse gold	Fine gold	Fine gold	
Gold	.902	.893	.917	.915	
Silver	.098	.107	.083	.085	
	Homestake	Highland	Terra	Deadwood	DeSmet
Gold	.820	.830	.825	.850	.820
Silver	.170	.155	.160	.140	.170

Concerning the history of the successive geological changes which have taken place in connection with these ores Mr. Devereux says: "First we have the proof that the gold veins and the contained gold were in existence, in much their present condition, prior to the Potsdam [Cambrian] period. Then we have the Potsdam seas washing away the debris resulting from the disintegration of the quartz veins, and depositing it in deeper water, in accordance with its various specific gravities. At the same time the gradual wave action carried the gold to the bed rock in the same manner as it is settled in a miner's pan. The Homestake vein, by reason of its greater durability, formed a reef or low island, which never became deeply submerged. After a time these sediments became insular, and as such remained undisturbed, gradually becoming cemented into rock, until the recent eruptions of porphyry took place, causing intense local metamorphic action. The gold which up to this time had suffered perhaps a loss in silver only, now became itself partially dissolved where the solvents were sufficiently powerful, and was again, at least partially, precipitated as thin films in the schists below.

"Once more a period of rest occupied the time, until the

*Devereux, Walter B. The Occurrence of Gold in the Potsdam Formation, Black Hills, Dakota, Am. Inst. Min. Eng., Trans. Vol. X. p. 465

erosive action of fresh-water streams cut through the upper strata and began to disintegrate the matrix of the gold, and afforded material for a new concentrating process. Disintegration and concentration have been going on until now, when the hand of man has hastened the work of nature.

"This gold from the conglomerate, which found its way down the slopes to the gradually lowering bottom of Deadwood gulch, was joined with new supplies brought from the Homestake vein through lateral gulches, and the result was the great Deadwood placer. That in Blacktail, however, received no new accession, and remained a placer which had received its gold entirely from the Potsdam sediment."*

The gold particles found in the cement are not large, seldom reaching a value of more than two or three dollars. Larger pieces are not uncommon in the Homestake quartz. The cement gold is made up chiefly of smooth, rounded, slightly flattened grains having a thin covering of iron oxide which is easily removed in the process of milling.

The value of the ore varies widely. During the early days of mining before the richer streaks were exhausted ore is said to have run as high as fifty dollars a ton with limited quantities near bed rock much higher. Today values as high as twenty dollars are occasionally found but the average in most of the mines is about four dollars. Large bodies, however, are said to average five dollars or more. Such bodies are found in various places along Blacktail gulch and elsewhere and some work is now being done upon them. Plate 6 gives a view up Blacktail gulch taken from the south side of Deadwood gulch at Gayville.

The free gold of the Cambrian is not confined to the conglomerate but is disseminated throughout the formation. Irving states that unaltered Cambrian shales and sandstones two or three hundred feet above the basal quartzite on the west bank of Spearfish creek have yielded from 80 cents to \$2.00 a ton. Free gold is said to be found also in unaltered glauconitic shales near Crown Hill, and the writer has heard many statements to the same effect concerning the sandstones and shales near Rockerville.

With few exceptions this gold above the basal conglomerate is of no economic importance. One important locality near

*The Occurrence of Gold in the Potsdam Formation, Black Hills Dakota. Am. Inst. Min. Eng., Trans. Vol. X, p. 465.



PHOTOGRAPH BY O'HARRA, 1901.

RUBY BASIN LOOKING WEST FROM SUGAR LOAF HILL.
Terry Peak on the left. Bald Mountain on the right.

Lead, the Hidden Fortune mine, has furnished several car loads of excessively rich ore, but the ore was found only a short distance above the conglomerate horizon, and may perhaps be rightly considered with the conglomerate ores. Plate 20 gives a view of this interesting locality. The gold was obtained from the open cut at the right of the building near the center of the view.

So far as known the refractory gold of the conglomerate, although averaging low in value, is in much the same condition as in the siliceous ores so abundantly developed in and above the lower quartzite. For a fuller description of these the reader is referred to the discussion of the siliceous ores in the following pages.

CAMBRIAN SILICEOUS ORES

The siliceous ores, known also as refractory ores and formerly as Potsdam ores, are found only in the northern Hills. The producing areas lie within Lawrence county and are two in number, designated by Prof. F. C. Smith as the Northern Connected district, lying chiefly to the west and southwest of Deadwood and Lead, and the Galena district, within which the town of Galena is situated.* Of the two the Northern Connected district is much the larger in areal extent and is the greater producer. Its chief centers of interest are: Ruby Basin, plate 7, Bald Mountain, Portland, Crown Hill, North Lead, Sheeptail Gulch, Squaw Creek, Spearfish Creek and Yellow Creek. In the Northern Connected district the ores carry some silver with the gold, while in the Galena district gold, silver and lead occur.

Igneous rocks of post-Cretaceous age have cut and intercalated the Cambrian strata in the districts mentioned to a marked degree. Phonolite, quartz-porphyry, etcetera have come up through the Algonkian metamorphics in the form of dikes, plate 8, and in many instances continuing as dikes have cut also through the Cambrian and Carboniferous rocks or, failing to do this, have spread out as extensive sheets, plate 9, or irregular masses or as well developed laccolites. Among these forms of intrusions the laccolites are by far the most conspicuous and important. The best illustrations are Sugar Loaf hill and Ragged Top mountain, but Terry peak, War Eagle hill and Bald mountain east of Spearfish creek, and Johnson peak, plate 10, west of

*The Potsdam Gold Ores of the Black Hills of South Dakota. Am. Inst. Min. Eng., Trans. Vol. XXVII., 1897, pp. 404-428.

Spearfish creek, between Bear gulch and Beaver creek have a similar origin. Sheets make up a smaller total amount of the eruptive material but their number is important. The thickness of the sheets varies from a few inches to two hundred feet or more, and indeed they pass by gradually increasing thicknesses into laccolitic masses. Irving states that the sheets vary greatly in their regularity and persistence, sometimes being short, thick and irregular, and again long, thin, and of great lateral extent; and that the more extended and persistent sheets lie between the heavy and less easily broken members of the Cambrian series, while those which assume a very irregular form are most commonly in the thicker horizons of very fine shales, where fracture is equally easy in all directions.* He estimates that these sheets in localities near the centers of eruption have increased the total thickness of the Cambrian formation nearly one fourth. The dikes are found in considerable numbers and occasionally become of importance. The materials of which these intrusive masses are made up are chiefly phonolite and quartz-porphyry. When found together the phonolite is observed always to cut the porphyry, indicating different periods of eruption, the phonolite being the later.

The ore is found at various horizons within the Cambrian, chief of which is immediately above the conglomeratic quartzite which lies unconformably upon the Algonkian schists and slates. The Stewart mine, plate 13, is an excellent illustration of the class. This horizon is easily distinguished and is generally known among the mining men as the "lower contact." Owing to the approximate uniformity of the higher shales and thin sandstones, plate 12, together with their many structural disturbances it has been difficult in many places to accurately locate the horizon of such ore bodies as occur within them. In the past it has been customary to refer to such deposits in a general way as "upper contact" ores. The proximity of some of these ore bodies to a heavy bed of scolithus sandstone known as the "worm-eaten" sandstone near the upper part of the Cambrian has possibly given origin to the name. Careful observation has revealed the fact that valuable ore bodies may be found at several horizons between the basal quartzite and the scolithus sandstone, hence the distinctive meaning of the term "upper contact" has largely disappeared. The lower contact ores are in many places underlain

*A Contribution to the Geology of the Northern Black Hills. *Annals N. Y. Acad. Sci.* 1899, Vol. XII. No. 9, p. 229.

by quartzite sufficiently auriferous to be classed as ore. This is particularly true of the North Lead, Yellow Creek and Ruby Basin areas and may upon further examination be found common in other localities.

So far as known all ore bodies worked in the Ruby Basin, Yellow Creek, Crown Hill, North Lead and Sheeptail Gulch localities are on or within the lower quartzite. On Squaw creek higher ores are worked, and in some places the definite horizon can be readily learned. At the Cleopatra the ore bodies are immediately beneath the scolithus sandstone, and this is stratigraphically about three hundred feet above the lower quartzite. Whether or not the lower ores are present has not yet been determined, but it is believed that exploratory work will reveal them. In the Portland or Green Mountain area all of the mines with one exception, the Decorah, are from two to three hundred feet above the base of the Cambrian.*

It must be borne in mind, as has been previously indicated, that igneous intercalations are frequent throughout much of the siliceous ore district, hence in estimating the thickness of the sedimentary series allowance must be made for the possible presence of the igneous rocks. This is illustrated in the following section observed in the Dacy shaft and drill hole at Ragged Top camp:

Shaft	
Limestone	505 feet
Drill hole	
Limestone	70 feet
Sandy lime shale	80 feet
Variegated shale	167 feet
Black shale	5 feet
Green sandy shale	5 feet
Black shale	17 feet
Phonolite	37 feet
Black shale	18 feet
Variegated shale	19 feet
Black shale	3 feet
Variegated shale	19 feet
Sand Rock	5 feet
Quartzite	23 feet
Trachyte, not passed through, ...	40 feet.

It is also illustrated in the partial view of the open cut on the Homestake property, plate 9. The mines in Green mountain near Portland are almost immediately beneath a phonolite cap. The American Express mine in Sheeptail gulch has a roof of porphyry and in the Sundance near Terry more than one-half

*Irving, John D. A Contribution to the Geology of the Northern Black Hills, Annals N. Y., Acad. Sci. 1899, Vol. XII. No. 9, p. 301.

of the ore is capped by similar material. The same is true in many places in the Big Bonanza on Fantail gulch and in the Decorah, and doubtless further investigation would show a like condition in many other mines. In the Union shaft in White-tail gulch a considerable body of phonolite which forms the base of the Sugar Loaf laccolite was penetrated before reaching the sedimentary deposits whose position beneath the opening of the shaft could be fairly accurately inferred from the outcroppings along the sides of the gulch in which the shaft is situated. In the Tornado shaft only shales and sandstones were encountered, plate 11. Most of the shafts in Ruby basin have a depth of less than three hundred feet. The Delaware shaft, however, about one half mile west of Aztec in the southern part of Ruby basin is said to have reached nearly six hundred feet in depth before encountering the Quartzite.

The structural relations of the Cambrian siliceous ores show some complexity but it is usually of such a nature as to cause no serious hindrance to the proper development of mining property. Folding is occasionally observed, faulting frequently occurs and the igneous intrusions sometimes aid in concealing true stratigraphic relations. Plate 11, which represents an east-west section through Terry, shows these features and readily indicates how it is possible to mistake one ore-bearing horizon for several.

Practically all of the siliceous ore bodies are in the form of shoots or channels in immediate connection with nearly vertical fractures running in a direction parallel to the longer diameters of the shoots. These fractures or "verticals" are usually slickensided and are frequently fault-planes along which more or less movement has occurred. This movement is well shown in the Cleopatra mine on Squaw creek where eleven ore shoots have been encountered and in each case there has been faulting varying from four to thirty feet. Figure 2 is a cross-section of one of these faulted ore bodies which in its general relation is characteristic of all. The ore shoots vary considerably in shape but in the main are greatly elongated bodies having a rounded or lenticular cross-section. They lie in a general north-south direction and are practically parallel with each other. Lateral branches or irregularities occasionally tend to conceal the parallelism but this is not frequent. The north-south direction is perhaps best shown in Ruby basin but in the southern part of this area they become deflected to the east. On Squaw creek the direction is



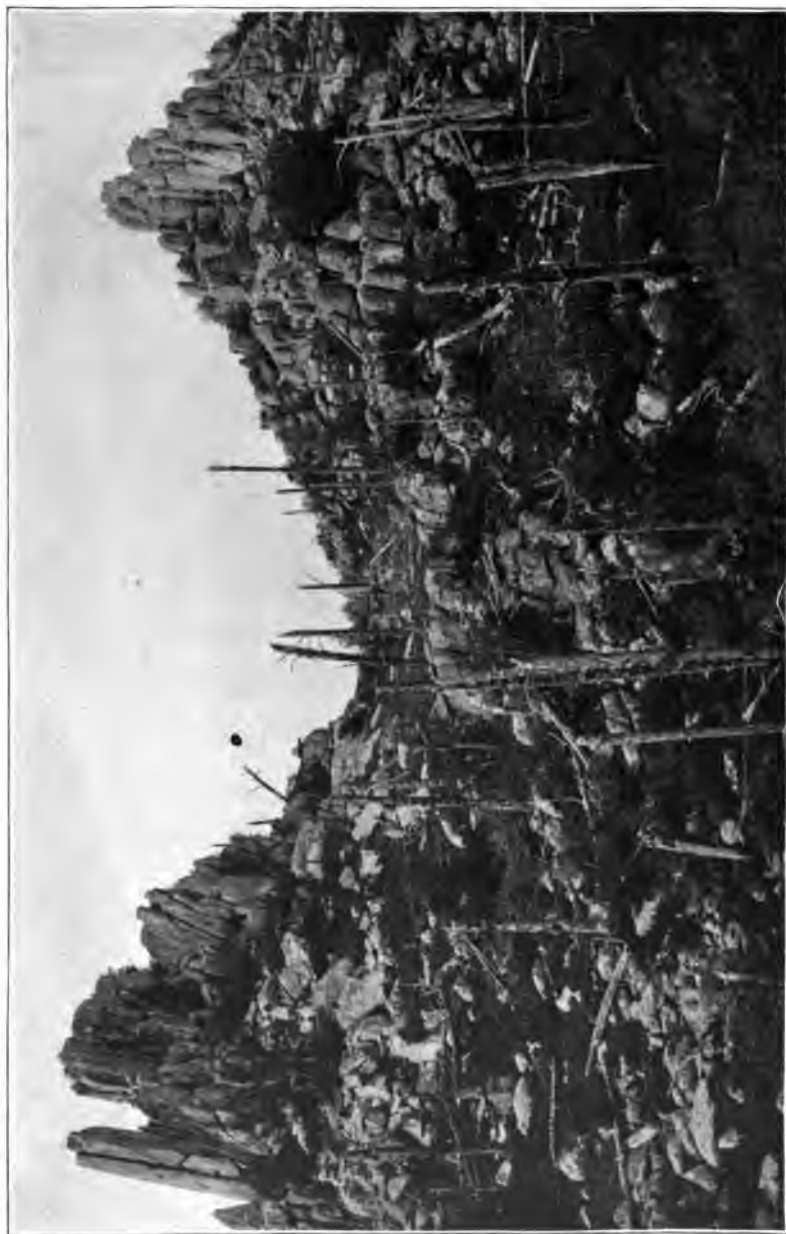
PHOTOGRAPH BY O'HARRA, 1901.

PORPHYRY DIKES IN ALGONKIAN SLATES NEAR PLUMA.



PHOTOGRAPH BY O'HARRA, 1901.

CAMBRIAN QUARTZITE WITH INTERCALATED PORPHYRY RESTING ON ALGONKIAN SLATES AND SCHISTS, HOMESTEAD OPEN CUT, LEAD.



PHOTOGRAPH BY W. H. FRITTS, 1901.

PORPHYRY NEEDLES AT TOP OF JOHNSTON'S PEAK NEAR BEAR GULCH.

nearly northwest-southeast. In the Portland area the direction is said to be approximately N 26° E. In the Galena district it is nearly east and west.

In all cases the ore shoots conform closely to the structure of the bedded deposits—locally known as the flat or blanket formation—with which they are found. The ore bodies, when not disturbed by movements subsequent to their formation are seldom bounded by well-defined walls, so that the change from ore to country rock is imperceptible by ordinary means and must be determined by frequent assay. The ores must contain values sufficient to meet the demands of the metallurgical processes by which they are treated; and whenever the average fails to reach the required standard the lower grade peripheral portions are not

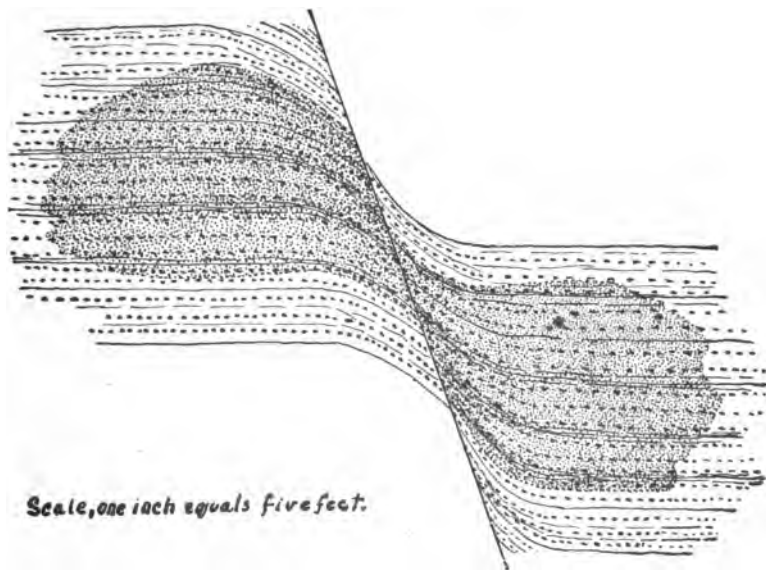


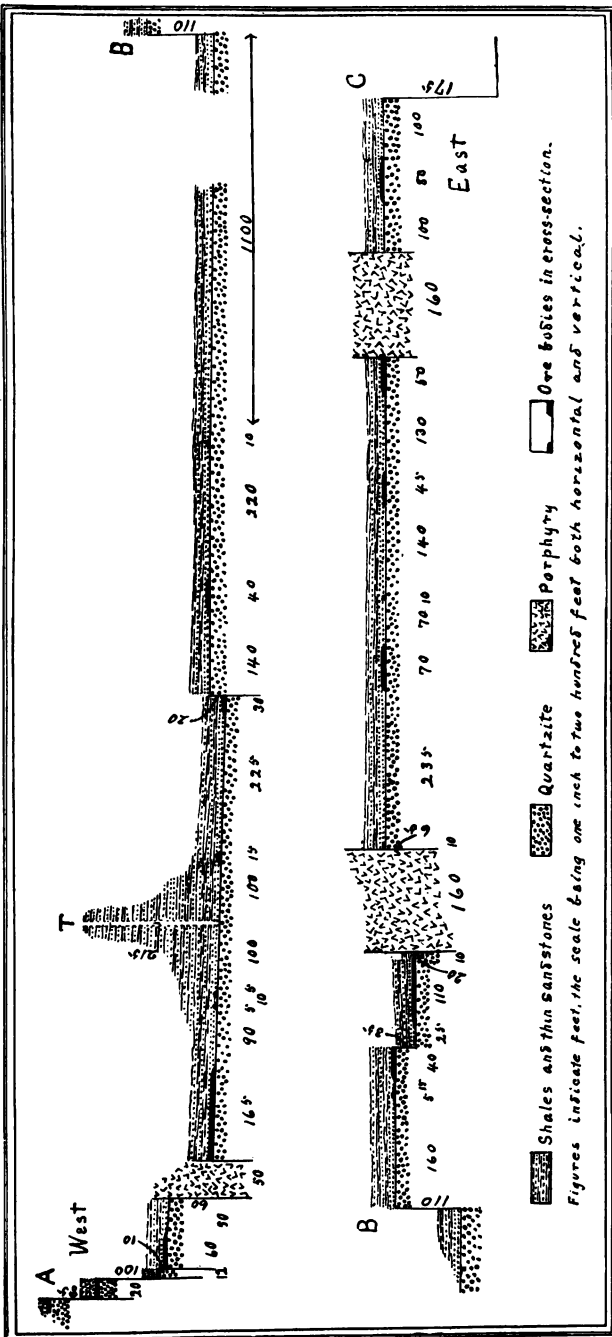
Figure 2—Cross-section of faulted ore body in the Cleopatra mine.

removed. It thus happens that in many instances the real limits of the auriferous portions are not learned, and in such cases the dimensions of the bodies are greater than those given on the mine maps. They vary from the almost imperceptible horizontal band or vertical seam along the fracture to a body having a thickness of fifteen feet, a width of more than one hundred feet, and a length of one half mile or more. In the Tornado mine, owned by the Golden Reward Company, one ore body has been worked one and one-half miles, and its terminals are not yet known. The widest place observed was one hundred seventy-

five feet. Another body, also owned by the Golden Reward Company, has been traced by workings a distance of five thousand feet, and in one place the pay ore reached a width of four hundred feet. Both of these are on the lower contact. Of the higher ore bodies, one in the Cleopatra mine on Squaw creek has been traced seven hundred feet, the greatest width being thirty feet. Doubtless a thorough examination of mine maps would show others fully as worthy to be noted. The distance between the ore bodies varies widely. The eleven ore bodies thus far discovered on the Cleopatra average sixty-five feet apart. In the Buxton mine the average is said to have been not more than fifty feet. Throughout much of the Ruby basin the distance is scarcely greater than the above. In the east-west cross-section through the Tornado shaft at Terry, plate 11, the width of the workable ore bodies aggregate 729 feet of the total 4,172 feet represented. This is nearly one fifth of the section and is a remarkable showing in view of the fact that one barren stretch of eleven hundred feet was encountered.

Exploratory work is carried on systematically and, as may be inferred by the foregoing descriptions, with a considerable degree of confidence. Whenever possible the ore bodies are reached by means of a tunnel or adit from the hillside, the opening being located in such a way that the drifting may be carried along at right angles to the general direction in which the ore bodies are believed to lie. This direction being approximately north and south over much of the siliceous area the exploratory tunnels run generally east and west. If the lower contact ores are being searched for the workings lie immediately upon the lower quartzite. On the higher levels local conditions govern the horizon to be explored. Where access to quartzite by means of tunnels from the surface is not convenient or possible shafting is resort to. In this way "sinking to quartzite" has become a common term among the mining men. By means of preliminary surveys the approximate thickness of the rock series to be penetrated may be learned and the amount of work required to reach quartzite estimated with reasonable accuracy. Quartzite being reached the exploratory work in the form of east-west drifts is prosecuted the same as along tunnels or adits entering from the hillsides.

The Cambrian siliceous ores are classified as blue or unoxidized ore, and red (or brown) or oxidized ore, the difference being that the red ore represents the weathered phase of the blue



EAST-WEST SECTION THROUGH TORNADO SHAFT, TERRY.

Faulted sedimentary rocks cut by porphyry dikes.

ore, the disseminated particles of iron oxide in the form of hematite (red) or limonite (brown) giving the color to the weathered material. No very definite rules can be formulated with reference to the relative position of the two sorts of ore. Naturally the weathered ore is found most abundantly near the out-crops or in those mines having a thin covering, while the blue ore is in larger proportion at considerable depths. In many places, however, doubtless due largely to local structural conditions red ore and blue ore occur intimately associated apparently without regularity of any kind. Frequently the ore breaks up into rounded or nodular blocks with concentric shells, the inner more consolidated portions being not infrequently made up of blue ore while the outward shelly portions are red or brown. This is known as "kidney" ore, and indicates in an excellent way that the red or brown ore is only a weathered form of the blue.

Sometimes the ore partakes of the nature of a soft clay. Certain mines near Portland have yielded considerable ore of this character, and many mines elsewhere have produced it in greater or less quantity. Recently Mr. Blatchford, of the Golden Reward Company, collected an extensive series of such soft ores from the Ruby Basin mines. Their color ranges from almost pure white through various shades of gray, yellow, red and brown to black. One peculiar bluish gray variety, known as "miners wax," is distinctly soapy in appearance and feel, soft when first taken from the mine, but like most of the other varieties becomes hardened after exposure for a few days in the air. The origin of these clay ores is not known, but they seem in general to represent a highly weathered condition of the porphyry. The values which they contain are not infrequently above the average.

Iron is present in the ore chiefly in the form of hematite or limonite in the oxidized ores and pyrite in the unoxidized ores. Sulphur is always present in the unoxidized ores. It occurs generally in combination with iron as pyrite, and occasionally with calcium as gypsum, with antimony as stibnite, and with barium as barite. Calcium and magnesium are rarely absent. Fluorite is abundant in a few localities. Copper minerals are not infrequent. Tellurium is present, it having been first observed by Dr. Richard Pearce in ore from the Welcome mine at Terry. Professor F.C. Smith has given some attention to its effect in metallurgical processes. Silver is present in varying quantity, its average being about two ounces to the ton.

Professor F. C. Smith gives analyses for oxidized and unoxidized ores as follows:*

Oxidized, (Red ore).

	per cent
Silica	84.45
Alumina	4.07
Ferric oxide	7.28
Calcium oxide	0.85
Magnesium oxide	0.25
Sulphur trioxide	3.71
Tellurium	8.426 oz. per ton
Gold	0.574 oz. per ton
Silver	2.875 oz. per ton
Total	100.61

Unoxidized, (Blue ore).

	per cent
Silica	68.748
Alumina	3.072
Iron	13.289
Sulphur	11.728
Gypsum	0.833
Fluorite	0.784
Phosphorus pentoxide	0.842
Tellurium	4.030 oz. per ton
Gold	0.325 oz. per ton
Silver	10.550 oz per ton
Total	99.296

The typical ores are reorganized sandstones and shales which in their unchanged condition carry a greater or less amount of calcium and magnesium carbonates. The rock when massive and not sufficiently auriferous to be of value is commonly known among the miners as "sand rock." The transition between the sandrock and the underlying quartzite is sometimes sharp and sometimes gradual. Irving states that in those localities where the transition is gradual the sand grains increase in abundance as one goes downward until the dolomite appears merely as a cement.

The ore bodies represent chemical replacements of the lime-magnesia material by siliceous solutions carrying gold, the deposition being a metasomatic interchange of silica, pyrite, etcetera, for the carbonates of lime and magnesia, whether the latter are present only as a cement or as the body of the rock. The carbonates doubtless acted as the precipitating agents. The source of the gold was evidently from the rocks beneath the Cambrian deposits. Whether or not it all came from the Algonkian meta-

*The Potsdam Gold Ores of the Black Hills of South Dakota, Am. Inst. Min. Eng., Trans., Vol. XXVII, p. 415.



PHOTOGRAPH BY O'HARRA, 1901.

MIDDLE CAMBRIAN SHALES AND SANDSTONES, DEADWOOD.

morphic rocks or partly from still deeper sources is uncertain.

Mr. J. D. Irving outlines the history of the formation of the ore bodies as follows: "First occurred the intrusion of the older quartz-porphyrtes, which produced much shattering. Contemporaneous with these, there may have been a certain amount of ore deposition, but not that to which the main siliceous ore bodies owe their origin. Later the eruption of the phonolites took place, cutting and shattering the older eruptives, and adding to the number of fissures in the sedimentary rocks. Subsequent to all of these intrusions, and probably separated from them by only a brief interval of time, came a long period during which heated solutions, containing fluorine and silica and other powerful mineralizers gradually replaced the carbonate of lime in the more soluble strata of the Cambrian. The chemical activity of these solutions was increased by the heat and mineralizers derived from the newly injected phonolites. They passed up through the Algonkian slates and schists, becoming much enriched by the leaching out of the gold from these rocks. Finally they reached the very calcareous and porous rocks of the Cambrian, and by a metasomatic interchange, produced the horizontal ore bodies that are found today."*

Many difficulties were encountered in the earlier treatment of these ores, hence the history of their development is a matter of some interest. Professor Smith gives the following facts in this connection: "The history of the Potsdam ores commences in 1877 when Mr. A. J. Smith, of Portland, South Dakota, located the Empire mine on Green mountain, and later the Trojan, Perseverance and Indispensable in the same vicinity. In 1879 the first engine was erected to supply power for the treatment of these ores; with it an arrastre was run upon ores from the Empire mine averaging about \$35 per ton. The saving in precious metals was little or nothing, and the attempt was discontinued after about two months. In 1880 the Portland Mining Company, owning the Portland, Gustavus and Pilgrim mining claims, built a mill (which still stands idle near the old town of Portland for the treatment of these ores by pan-amalgamation; later this company purchased the Empire, Trojan, Indispensable, Perseverance, Folger and Olive claims. Pan-amalgamation saved about fifty per cent. of the silver and thirty per cent of the gold, and

*A Contribution to the Geology of the Northern Black Hills. N. Y. Acad. Sci. Annals, 1899. Vol. XII, No. 9, p. 311.

various other processes, such as "free-milling," kiln-roasting and chlorination, and cyanide lixiviation were tried without success. In 1883 the Welcome Mining Company passed through a similar history of unfortunate metallurgical experiments upon their property near the head of Fantail gulch. In 1886, the Buxton mill was built by the Buxton Mining Company, and experiments made there by Mr. O. P. Ankeny, by the use of bromine, seemed to have stopped just short of success, probably on account of disadvantages which, at the present date, would not surround the experiment.

About this time the siliceous ores were successfully treated by the Plattner process in the metallurgical department of the School of Mines. In 1899 the Golden Reward Gold Mining Company erected a plant in Deadwood for the treatment of the Potsdam ores by barrel chlorination, commencing in April, 1891, with a capacity of fifty tons per day. In 1890 the Deadwood and Delaware Smelting Company built the small experimental smelting plant in Deadwood, which has since grown so largely. Two years later, or in 1892, a small cyanide plant was erected in Deadwood by the Black Hills Gold Extraction Company; and in November, 1895, the Kildonan Milling Company started chlorination works at Pluma, South Dakota (a short distance from Deadwood), with a capacity of about seventy-five tons per day**

Prior to the erection of the Deadwood and Delaware smelter (now the Golden Reward smelter) and the Golden Reward chlorination plant (destroyed by fire in 1899) both of which proved successful, siliceous ore assaying less than about \$30 a ton could not be utilized. By 1894 the processes had been sufficiently perfected to allow for the profitable treatment of \$15 ore. Since the recent introduction of the cyanide process ores much below \$15 have proven profitable and in favorable instances, where mining is easy and coarse crushing is admissible, ores as low as \$4 have yielded fair return.

CARBONIFEROUS SILICEOUS ORES.

Gold was discovered in remunerative quantities in the Carboniferous limestone, near Ragged Top mountain in 1896. A shaft had been sunk in 1886 on the Silver Ridge property north of the mountain, the rock there having something of the appearance of the silver bearing rock of the Iron Hill mine to the north

**The Potsdam Gold Ores of the Black Hills, Am. Inst. Min. Eng., Trans., 1897, Vol. XXVII, p. 404.



STEWART MINE ON LOWER QUARTZITE, NEAR TERRY.

PHOTOGRAPH BY O'HARRA, 1901.

east but nothing of permanent value was found and the shaft was abandoned. Ten years later, however, a fortunate assay of material found three hundred yards west of the Silver Ridge shaft gave a value of \$200 in gold to the ton. Other good ore was quickly found and a local boom immediately followed.

The discoveries of importance referred to were made on detached boulders or fragments but further prospecting located the ore in long fissures or "verticals" both to the north and to the south of Ragged Top but chiefly to the north on what is known as the Dacy or Balmoral flat. These so called verticals are perpendicular crevices in the massive limestone partially or wholly filled with a siliceous mass of brecciated limestone containing more or less iron oxide and calcite. Active mining operations were carried on along these verticals, seven in number, during the years 1896-97 and then ceased, the ore becoming too lean to be profitably worked.

The greatest thickness of the verticals at the surface was approximately ten feet but all are said to have become narrower with depth. The average depth of ore of sufficient value to work, at that time approximately twenty dollars in gold to the ton, was about sixty feet, although the Balmoral and the Dacy considerably exceeded this depth. The Dacy vertical, the largest producer, has been traced along the surface a distance of two thousand feet or more. Its direction is N 35° W and the general trend of the other verticals is about N 45° W. The walls are illy defined, lateral enrichments sometimes occur and the ore when not brecciated is scarcely different in appearance from the lean or barren limestone enclosing the ore body. The ore is usually slightly darker, however, and is harder owing to the presence of the silica. Professor Smith gives the following analysis of Dacy ore:*

	per cent
Moisture	0.110
Volatile matter	0.802
Silica	90.990
Alumina	2.970
Ferrous oxide	3.024
Calcium oxide	1.138
Magnesium oxide	trace
Tellurium	29.26 oz per ton
Gold	17.34 oz per ton
Silver	1.21 oz per ton

Total.....99.034

*The Potsdam Gold Ores of the Black Hills, Am. Inst. Min. Eng., Trans., Vol. XXVII, p. 418.

A few miles north of Ragged Top mountain on the Cleopatra property a small vertical has been found in the limestone, apparently similar in every way to those found on the Dacy flat. This has not been exploited.

The Ulster mine situated a little to the east of the Dacy flat proper shows a different occurrence of the ore, the origin, however, being evidently much the same as those of the Dacy type. I quote Mr. Irving concerning the nature of this deposit: "In the Ulster mine the ore occurs in contact zones, between the limestone and a very irregularly intruded mass of porphyry. This is cut by a dike of dense green phonolite, and the ore seems to have resulted from the silicification of brecciated limestone which has been fractured by the intrusion of Twin Peaks and other porphyry bodies in the Cambrian below. Brilliant purple fluorite occurs in great quantities. The ore is irregularly distributed. It may thin to a mere streak, and again open out to a very large and thick mass. The values obtained are very high, running frequently up to \$150 per ton, and in one instance \$1,000 per ton."*

The total output of the verticals north of Ragged Top including the Ulster has been estimated at \$250,000. The principal producers have been the Dacy, the Balmoral, the Ulster, the Ragged Top, the Sterner, the Little Bud and the Doyle. No statistics are at hand giving the production of the verticals further south.

After active work upon the verticals had ceased the discovery was made that the massive limestone itself is sometimes impregnated over considerable areas with an encouraging percentage of gold. In several places, particularly to the south and southwest of Ragged Top mountain, it has been learned that with metallurgical processes now available this impregnated material can be treated at a profit. The pioneer company in the development of this sort of ore is the Spearfish Gold Mining and Reduction Company, their property lying on the high limestone flat between Ragged Top mountain and Spearfish canyon. A two hundred fifty ton cyanide plant, built by the company in 1899 continued in successful operation until its destruction by fire in October, 1901. During the past summer the Deadwood Standard Mining Company erected a cyanide plant immediately south

*A Contribution to the Geology of the Northern Black Hills, N. Y. Acad. Sci. Annals, 1899, Vol. XII. No. 9., pp. 313 and 314.

of the Spearfish company's property, the ore on the two properties being practically identical. Other plants are now in process of erection.

The ore is in close association with intrusions of trachytoid phonolite, the origin of the ore being due to the presence of the igneous rock. A shallow shaft on the Spearfish property cuts through six feet of phonolite with ore above and below, while in a tunnel on the same property the roof is phonolite, the ore lying immediately beneath.

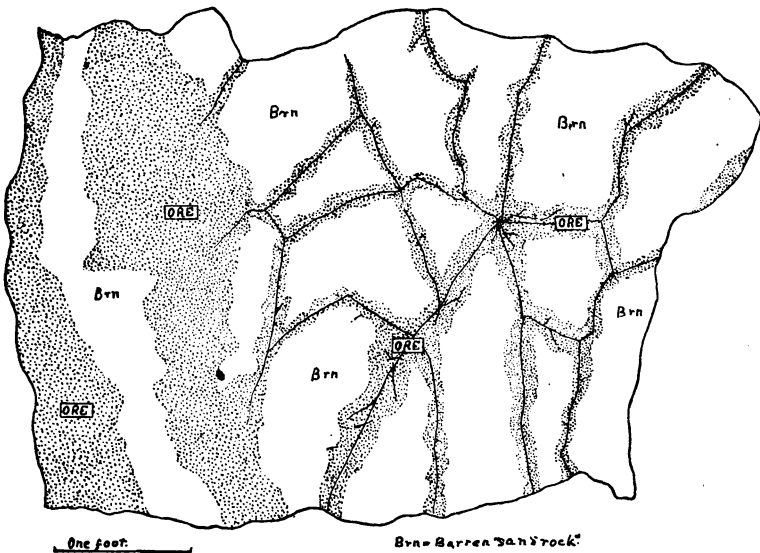


Figure 3—Horizontal section showing impregnation of sandstone along vertical joint planes, Cleopatra mine.

The ore looks much like ordinary gray limestone weathered to a rather soft and porous condition and containing iron oxide and silica. The gold content is not high but the ore is easily mined and cheaply treated, hence may be worked with considerable profit. On the Spearfish ground where the ore body is most extensively exploited the ore under favorable conditions of weather is simply blasted out in large open pits. Tunnels for underground winter work have been made, but they nowhere extend far beneath the surface. In the neighboring properties similar conditions of mining and treatment prevail.

One feature of interest in connection with the ore, but which has not received careful study is the apparent occurrence of the

values along well-developed or incipient joint planes. The ore demands much less crushing than is generally the case with the more highly siliceous ores, particularly the Cambrian quartzite ores. In some of the Yellow Creek mines, however, coarse crushing is sufficient for quartzite and it is possible that in such instances the gold content is also distributed along the illy disclosed joint planes. This condition of distribution is beautifully shown on an enlarged scale in one part of the Cleopatra mine, as illustrated in figure 3, where the quartzite joint blocks are impregnated with gold chiefly along the joint planes.

The origin of the Carboniferous gold ores is practically the same as that of the Cambrian ores. Siliceous solutions carrying gold have removed original calcite leaving silica instead, the exchange taking place subsequent to the intrusion of the igneous rocks in post-Cretaceous time. The ore bodies are vertical on the Dacy flat, irregular in the Ulster, and approximately horizontal in the locality west and southwest of Ragged Top. The intrusions have affected the country rock differently in the different localities and the various positions and shapes of the ore masses are simply due to the form and direction of the particular fissure through which the solutions reached the limestone.

PLACER DEPOSITS.

Placer gold is found in the gravel bars of all of the present streams and in the various terraces which line their valleys. Few of these deposits have failed to yield gold in paying quantity and many have produced handsomely. French and Castle creeks were first successfully prospected, but Rapid creek, Battle creek, Whitewood gulch, Spearfish creek, and their tributaries followed quickly thereafter. The richer deposits of all the streams are now either practically exhausted or are in such position with reference to water supply that they can no longer be worked extensively with profit. Large bars on bedrock in some of the creeks where water is abundant but where the gold content is low, are receiving some attention. With improved appliances and wise methods these may yet yield considerable profit.

Most of the placer gold during the height of the placer mining activity was obtained by the simple methods of panning, rocking, and ordinary sluicing. Sluicing was carried on wherever possible, but in many of the gulches flowing water was available in quantity only during the early part of the year, while the melting snows and the spring rains were contributing to the volume

of the streams. For this reason the light rocker, easily carried or wheeled from one reservoir or pool of water to another, was often utilized. The Rockerville mining camp was especially noted for the large number of these rockers, hence the name of the camp as well as the name of the gulch on which the camp was located. Here by this simple method during the years 1877-79 gold to the amount of approximately one half million dollars was obtained. Even at the present time the rocker may be seen occasionally in use on this gulch, where fair wages may be obtained by the careful workman, although hampered by the necessity of bringing the gravel from the pit to the waters edge by means of a wheelbarrow.

In general the sluicing was of the most economical nature. Shallow ditches and temporary flumes were made by the individual claim owner or by the combined energies of the several owners of adjoining claims and the gold separated by the water thus obtained.

In at least three instances hydraulic mining was attempted, namely, at Rockerville, near Pactola, and along Battle creek. The Rockerville enterprise, perhaps the most extensive of the three, consisted in the building of a seventeen mile box flume from a reservoir on Spring creek two miles above Sheridan along a winding and difficult mountain course to the high "dry diggings" near Rockerville which extend as much as four hundred fifty feet above the bed of Spring creek one and one-half miles to the north where that stream approaches nearest the deposits. The flume, built by the Black Hills Placer Mining Company, was begun in 1878 and was completed two years later at a cost of \$210,000. Operations were carried on for about two years and approximately \$500,000 in gold obtained. Litigation then suspended operations and the flume was abandoned. About the year 1880 the Estrella del Norte Company constructed flumes aggregating several miles in length above and below Pactola on Rapid creek where work was prosecuted for several years with indifferent success. The third effort was made by the Harney Hydraulic Gold Mining Company in 1883. In the attempt to secure sufficient water both Grizzly gulch and Battle creek were tapped, the flumes uniting at the mouth of Grizzly gulch and extending as one flume down Battle creek to Mitchell's bar below the present site of Keystone. Some gold was obtained but this enterprise like the two others was soon abandoned without reaping the return hoped for.

The most noted placer localities were those of Deadwood, Nigger Hill and Rockerville. The Deadwood area, plate 14, included the following important gulches: Deadwood (sometimes known as the great bonanza gulch of the Hills), Whitewood, Gold Run, Blacktail and Bobtail. In the Nigger Hill district the principal placer streams were: Bear gulch, Potato gulch, Nigger gulch, Sand creek, Poplar gulch, and Mallory gulch. The Rockerville area was made up chiefly of a high terrace several square miles in extent, together with the various small gulches leading off from the terrace. The rich nature of the Deadwood placers was discovered in November, 1875, at which time Discovery claim was located by William Lardner and others on Deadwood gulch a little below the mouth of Blacktail gulch. The Nigger Hill deposits were discovered a few weeks earlier than those of the Deadwood locality, while the Rockerville gold was not found until more than a year later. Many other localities, although not producing so largely as those given, have nevertheless added greatly to the total output.

Some streams of considerable importance lie mostly within areas covered by stratified rocks and have had little opportunity to collect and concentrate gold. Box Elder creek and Elk creek, as well as most of the streams south of French creek, are of this class. Concerning the French creek placers, over which there has been much disappointment, Prof. Jenney says, "I regard the poverty of the French creek deposits, compared with those afterward discovered on the streams farther north, to be due to a deficiency in the source of supply, owing to the small area drained by the stream, the small amount of denudation to which the ledges in this area have been subjected, and to a want of sufficient grade in the valley to cause a concentration of the gold into a pay channel. Had all the gold diffused through the valley of French creek been concentrated into a narrow lead or pay channel, it would have made claims as rich as the most enthusiastic miner would have desired."*

The high valleys of French creek and Battle creek lie among granites and schists chiefly, while the streams farther north traverse areas made up mostly of shales, quartzites and late eruptives, the main trend of the streams in nearly all cases being across the general strike of the upturned rocks. The character of the rocks has much to do with the nature of the stream valleys

*Report on the Geology and Resources of the Black Hills of Dakota with Atlas, 1880, p. 238.



PHOTOGRAPH BY O'HARRA, 1901.

THE GOLDEN REWARD SMELTER, DEADWOOD.
(Formerly known as the Deadwood and Delaware smelter.)

and therefore of the gold concentration. The schists give way to broad valleys and parks checked here and there by peaks and ridges of harder rocks, while the quartzites and siliceous slates by their greater resistance to weathering action present steep slopes and precipitous canyons along the bottoms of which the energetic streams must thread their way.

Of all of the streams Rapid creek leads in the areal extent of its placer deposits. For forty miles these deposits line its course and range in successive steps from the creek bed to various heights above. Much of the gold is in fine particles, particularly below the union of Castle and Little Rapid creeks, and much of the placer material is made up of heavy boulders so that it is not easy to secure the values.

The gold lies chiefly upon or near the bedrock, although occasional streaks of value are found higher in the deposits, the deposits being made up of a heterogeneous mixture of sand, pebbles, boulders, clay, etcetera, collected from the surrounding country rocks.

The gold from the various streams differs slightly in color and other physical characters and in chemical composition, but in all cases a high percentage of purity is shown. The following analyses indicate this fact:

	Gold	Silver	Base Metal
Spring creek*.....	937.8	45 9	16.3
Spring creek*.....	946.4	50.4	3.2
Spring creek**.....	934.	49.	16.
French creek**.....	933.	55.	12
Rapid creek**.....	940.	60.	—
Deadwood gulch**.....	907.	93.	—

Castle creek and Battle creek have yielded considerable coarse gold as have also the many streams of the northern Hills, particularly those of the Nigger Hill district. The following record of the largest Black Hills nuggets has been collected with care and although incomplete is believed to be correct so far as given: Nugget on Discovery claim, Bear gulch, found in 1875 by Portigee Frank, value \$18; nugget on Montana bar near Sheridan, 1875, name of finder unknown, value, \$23; nugget on claim No. 32, Bear gulch, 1876, by John McTigue, value \$51; nugget on claim No. 28, Potato creek, 1876, by Frank Manty, value \$146; nugget on claim No. 23, Bear gulch, 1877, by E. St.

*Jenney, W. P. Report on the Geology and Resources of the Black Hills, 1880, pp. 249-250.

**Scott, Samuel, Map of the Black Hills, Custer, 1897, p. 6.

John, value \$57; nugget on claim No. 31, Bear gulch, 1877, by E. St. John, value \$56; nugget on claim No. 12, Potato creek, 1877, by Frank Manty, value \$90; nugget on Mallory gulch, 1878, by John Majors, value \$81; nugget on Centennial gulch, 1878, by Peter Thorson, value \$120; nugget (the largest ever found in the Black Hills) on Claim No. 37, Bear gulch, 1879, by "Doc" Wing, value \$465; nugget on Claim No. 16, Bear gulch, 1879, by David Gillespie, value \$54; nugget on Sand creek, 1881, by William Bell, value \$78; nugget on Claim No. 12, Bear gulch, 1882, by E. St. John, value \$51; nugget on Mallory gulch, 1883, by M. R. Hydliff, value \$117; nugget on Claim No. 5, Bear gulch, 1887, by James McCoun, value \$53; nugget on Ruby gulch, 1890, by Samuel Moll, value \$27; nugget on Sand creek, 1893, by M. R. Hydliff, value \$63; nugget on Poplar gulch near the Inter Ocean mine, 1893, by Messrs. Heavirlan and Mulheisen value \$57; nugget on Lightning creek, 1899, by Lee and Charles Carr, value \$43. Most of these nuggets were well rounded pebbles of gold almost or quite free from extraneous matter. The \$465 and the \$117 nuggets were exceptions, a considerable part of their volumes being taken up by quartz.

Associated with the gold in the placers are garnets, hematite and limonite pebbles, columbite, tantalite, cassiterite and other less noticeable minerals. The garnets are abundant in most of the streams, particularly in those of the central and southern Hills. Columbite and tantalite are not uncommon in the Harney Peak region and are abundant in the Nigger Hill district. Cassiterite occurs in pretty much the same streams as the columbite and tantalite, it being found in such abundance in the Nigger Hills gulches as to have furnished considerable annoyance to the miners before its nature was learned. It is now a source of not a little profit. Platinum, although diligently searched for, appears not to have been found. Professor Carpenter mentions the finding of remains of the mammoth, *Elephas primigenius*, and recently a well-worn tooth found near Hayward was presented to the State School of Mines.]

TAILINGS.

It is well known that in the various processes for treating ores more or less of the values fail of extraction. Occasionally in the past this has been a matter of consequence, but within recent years careful study of the metallurgical needs of the various ores has greatly lessened this loss.

During the past two years a small cyanide plant has successfully treated the tailings of the now dismantled Rapid City chlorination works and at the present time a small plant is treating the silver-bearing tailings from the old Iron Hill works near Carbonate.

Attention has also been directed to the vast quantities of tailings from the Homestake mills scattered along the bed of Whitewood creek for a distance of several miles below Lead. Previous to the installation of the great cyanide plant near the mills much of the concentrates were saved and smelted, but considerable values escaped into the creek. This material has been more or less concentrated by the ordinary stream action, but in a few instances special effort has been exerted to collect it in localities favorable for future operations. Plate 17 gives a view of a large body of these tailings collected at Pluma, between Lead and Deadwood. During the past summer four small cyanide plants have treated these tailings in as many different places on Whitewood creek.

METHODS OF TREATMENT.

The gold ores of the Black Hills as indicated on the previous pages are free-milling, partly free-milling and refractory.

The treatment of the free-milling ores present few difficulties, the ordinary amalgamating stamp mills securing the values in a highly satisfactory manner. The refractory ores are more complicated. Other things besides the refractory nature of the ores, such as richness, conveniences for shipping, competitive prices for treatment, etcetera enter into the selection of the method to be adopted.

At the present time two methods of treatment prevail, namely, smelting and cyaniding. Chlorination processes entered into the earlier treatment, large plants having been erected at Pluma, Rapid City and Deadwood. None of these are in operation.

For more than ten years the Golden Reward smelter, formerly known as the Deadwood and Delaware smelter, of Deadwood has been successfully treating large quantities of medium and high grade siliceous ores, chiefly from the Bald Mountain Ruby-Basin region. In addition to this smelter in Deadwood another large one with extensive modern improvements is now building in Rapid City.

Recently much interest has been shown in the development

of the cyanide process, the low grade oxidized siliceous ores readily yielding their values by this method.

At the close of the year 1901 six cyanide plants were in successful operation on various ores, the largest being the Homestake tailings plant with a capacity of thirteen hundred tons daily. Eight other plants were completed but of these two had been destroyed by fire, one was dismantled and five were inactive. Six other plants are now in course of erection.

The partly free-milling ores combine the methods of treatment of the free-milling and the refractory ores. Such of the values as are free are extracted by amalgamation and the concentrates are sent to the smelter.

Individual ores present their peculiar difficulties and the details of treatment in each plant vary in many ways, but it is no purpose of this paper to enter into a description of the various methods. Most of the literature on the subject is readily accessible to those interested.

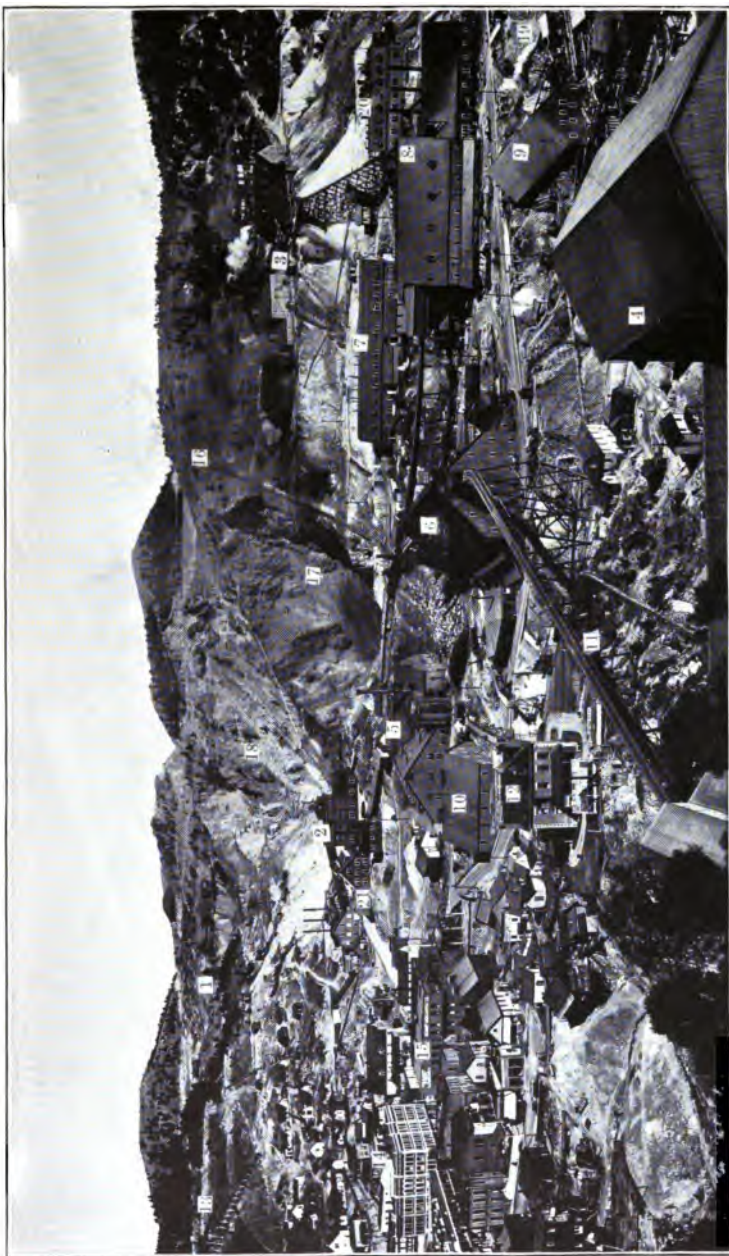
OUTPUT.

In a short paper entitled "The Production of Gold in the Black Hills." published in The Aurum, Vol. 1, No. 1, Rapid City, South Dakota, I have considered the merits of various estimates of the output of gold from the Black Hills. Without entering here into the details of that paper, it may be said that in the light of all available sources of information the following series of statistics expressed in round numbers appears to represent with fair accuracy the annual gold output:

1875.	\$ 10,000	1889.	\$2,900,000
1876.	1,400,000	1890.	3,200,000
1877.	2,000,000	1891.	3,600,000
1878.	3,000,000	1892.	3,700,000
1879.	3,600,000	1893.	4,000,000
1880.	4,200,000	1894.	3,900,000
1881.	4,000,000	1895.	3,900,000
1882.	3,300,000	1896.	5,000,000
1883.	3,200,000	1897.	5,700,000
1884.	3,300,000	1898.	5,700,000
1885.	3,200,000	1899.	6,500,000
1886.	2,700,000	1900.	6,200,000
1887.	2,400,000	1901.	7,000,000
1888.	2,600,000		
Total.....		\$100,210,000	

FUTURE PROSPECTS.

The annual gold production of the Hills, as indicated in the above table, has increased almost steadily for a number of years. In the earliest history of the Hills placer deposits furnished the



PHOTOGRAPH BY CROSS, 1901.

HOMESTAKE MILLS, HOISTS AND OPEN CUTS, AT LEAD.

- | | | | |
|-------------------------------------|-------------------------|---------------------------------|--|
| 1. Highland hoist and saw mill. | 5. Homestake mill. | 11. Steel bridge. | 15. Office, Hearst free library and company store. |
| 2. Golden Star hoist. | 6. Golden Star mill. | 12. Superintendent's residence. | 16. Wood chutes. |
| 3. Old Abe hoist. | 7. Amicus mill. | 13. Coal chute. | 17, 18. Open cuts. |
| 4. Ellison hoist. | 8, 9, 10. Plate houses. | 14. Hotel Smead. | 21. Miners' bath and dressing rooms. |
| 19. Old experimental cyanide plant. | 20. Shop. | | |



PHOTOGRAPH BY O'HARRA, 1901.

THE GOLDEN REWARD SMELTER, DEADWOOD.
(Formerly known as the Deadwood and Delaware smelter.)



PHOTOGRAPH BY O'HARRIS, 1901.

THE KILDONAN CHLORINATION PLANT, PLUMA.
Deposit of Homestake tailings in front on the right.



PHOTOGRAPH BY O'HARRA, 1901.

THE CLEOPATRA MINE AND CYANIDE PLANT, SQUAW CREEK, NEAR CARBONATE.

chief output, and were practically exhausted before the cement ores became of importance. The cement ores in turn declined almost coincidentally with the rising influence of the Homestake belt. The Homestake belt continued for several years the only extensive producer, the quartz vein and other mines generally showing little disturbance of the annual output.

With the discovery of successful metallurgical processes by which the values in the siliceous ores could be saved, a new and important factor in the gold production was introduced. The tendency has been to continually lessen the cost of treatment of the siliceous ores, so that lower grades of ore could be utilized. Thus it has happened that the siliceous ore mines now rival the Homestake in output, even though the latter has greatly enlarged its working equipment. As a consequence two constantly growing factors are at present aiding each other in swelling the production, while never before has there been so great activity in the mines not classed with the siliceous ore and the Homestake mines.

Individuals or companies with sufficient means to properly prospect for ore bodies, and influenced by intelligent study of geological conditions, are constantly disclosing abundant values in localities formerly supposed to be barren. Indeed it may be said that new ore bodies of low and high grade are revealing themselves as rapidly now as at any time in the history of the region, and there is every reason to believe that for many years to come the annual output of gold will continue enhancing in value.

COPPER.

The first prospectors in the Black Hills noted the presence of copper and a few claims were early located. Among the earliest of these were the Blue Lead, (pronounced leed) one mile east of Sheridan, the first county seat of Pennington county, and the Black Hills Copper Company's property, six miles west of Rochford, also in Pennington county. For many years little more than assessment work was done on any of the properties located, and although considerable interest has centered around some of the claims, none were exploited sufficiently to establish their value.

The constant demand for copper ore at the local smelters for use in the reduction of the refractory gold ores, and the enhanced value of the metal during the past two or three years, has greatly heightened the interest in the copper possibilities of the

Hills. Many new claims have been located, abandoned claims have been relocated and worked with greater energy, and in a few places many thousands of dollars have been spent in the effort to find deposits of positive value.

The deposits, in so far as surface conditions seem to indicate them, are numerous, extensive and well distributed, but as yet none have become steadily productive. Some study has been made of their relative positions, and while the properties located are commonly spoken of as being roughly arranged along two north and south belts, one near the central portion of the metamorphic area and the other near its western edge it is doubtful if this relationship is an important or even a real one. Beginning with the Blue Lead, near Sheridan on Spring creek, and going northward we find near Pactola on Rapid creek the Poisoned Ox, the Copper Reef and the Copper Glance. On the county line near the head waters of Bogus Jim creek is the Rio Tinto. Further north, one-half mile southeast of Nemo on the Box Elder, is the Holy Fright, and three miles northwest of this is the Copper Castle. The line then gradually deflecting more to the west, crossing Elk creek near Elk Creek station, crosses Windy Flats north of Perry, then by rather obscure outcroppings reaches Deadwood within the city limits of which considerable exploratory work has been done. Occasional prospects are reported extending from Deadwood southeastward to the county line near which are grouped the Copper Cliff, the British American and the Black Hills. These lie near the south fork of Rapid creek, northwest and west of Rochford. Southward two or three miles is the Reynolds property, and still further south the Palmer property. West of Hill City is the Mastiff and beyond this southward are the Truax and the Vigilante. Other prospects of more or less interest lie along the lines indicated, while some have been found having no apparent relation to these lines.

Practically all of these properties carry a copper stained gossan, some of them showing in great quantity and not infrequently with a considerable amount of copper. In sinking through this gossan a leached material known as "ash" is reached. This is a soft black decomposed slate quite free from minerals of value.

Thus far no one has gone through this ash, but the Black Hills Copper Company is now working to this end, their inclined double compartment shaft of eight hundred feet having pene-

trated beneath the surface to a perpendicular depth of more than 400 feet. At the Blue Lead a tunnel cutting below the surface outcroppings a perpendicular distance of more than six hundred feet has penetrated the unchanged or only slightly changed slates, charged with iron and copper pyrites. Thus, notwithstanding the great amount of work done, the lower limit of the ash is not yet reached, and the conditions in the zone between the ash and the sulphides remain to be learned.

The Black Hills copper deposits are frequently compared with the Ducktown, Tennessee, deposits, and with apparently much reason. The country rock is much the same in general character, the structure is not greatly different, the general dip of the veins approximately the same, the gossan or iron hat in each instance well developed, the leached and decomposed slates equally prominent, and the sulphides below contain more or less copper. Nickel is said to be present in the Black Hills. The chief similarity to be yet established, if such similarity exists, is in the intermediate zone not yet penetrated in the Black Hills, but which being the horizon at which were found the valuable enrichments of sulphide the Ducktown deposits holds, perhaps, the key to the successful development of the Black Hills deposits. That such enrichments exist here is quite possible, and the indications are that they may be found.

Mr W. H. Weed, of the United States Geological Survey, has recently set forth in a very clear manner the general conditions governing the enrichment of mineral veins by later metallic sulphides, and while not including references to the Black Hills deposits, the evident application to this region of many of the facts presented by him, makes his paper one of particular value at the present time to those interested in the development of Black Hills copper properties. He indicates how the leaching of a relatively lean primary ore, commonly by surface or descending waters; but occasionally by deep-seated waters, will supply the material in solution for such enrichment; how the unaltered sulphides, especially pyrite, will induce precipitation; how the material precipitated is crystalline; how a number of mineral species are commonly formed, and are now forming in veins by such reactions; and how such minerals deposited in quantity may form ore bodies of considerable size (bananzas) or may be disseminated through the lean primary ore in strings and patches, thus enriching the ore body as a whole and even making a former low grade body of sufficient value to work. Con-

cerning the chemical reactions involved in the leaching of the gossan zone he says, "Surface waters descending through the relatively porous and open textured gossan of a vein, are normally oxidizing, and on passing downward usually attack the unaltered sulphides and deepen and extend the zone of the gossan. As the waters descend they are robbed of their oxygen by the sulphides which they decompose, and percolating further downward, the waters which at first were strongly oxidizing in character, are now charged with various salts, and frequently with free sulphuric acid. They are still descending waters of surface origin, but have lost all the characters commonly ascribed to surface waters. This change is, of course, due to the reactions involved in the changing of the vein minerals to gossan. The common metallic sulphides of veins are pyrite, pyrrhotite, chalcopyrite, tetrahedrite, enargite, bornite, galena (with which quartz is most commonly associated as a gangue mineral) and a little less commonly calcite and other carbonates, and brite, et cetera. The changes by which this mixture is converted into a mass of porous, more or less pure limonite are briefly as follows: The pyrite alters to a mixture of iron sulphates and sulphuric acid, which, reacting on more pyrite, eventually forms a mixture of hydrated oxides (limonite ores). The reactions commonly assumed are as follows:

1. $\text{Fe S}_2 + \text{O}_3 + \text{H}_2 \text{O} = \text{Fe}_2 \text{S} + \text{H}_2 \text{SO}_4$
2. $\text{Fe S} + \text{H}_2 \text{SO}_4 = \text{Fe SO}_4 + \text{H}_2 \text{S}$
3. $\text{Fe S}_2 + \text{O}_2 + 2\text{H}_2 \text{S} = \text{Fe S} + 2\text{H}_2 \text{O} + 3\text{S}$
4. $\text{S} + \text{O}_3 + \text{H}_2 \text{O} = \text{H}_2 \text{SO}_4$
5. $2 \text{Fe SO}_4 + \text{O} + \text{H}_2 \text{SO}_4 = \text{Fe}_2 (\text{SO}_4)_3 + \text{H}_2 \text{O}$
6. $\text{Fe S} + \text{Fe}_2 (\text{SO}_4)_3 = 3\text{Fe SO}_4 + \text{S}$

Pyrrhotite, if present, is attacked as in the second equation given. * * * * Chalcopyrite being $\text{Cu}_2 \text{S}$, $\text{Fe}_2 \text{S}_3$, the iron sulphide molecule yields more readily to attacking solutions of ferric sulphate (which by hydrolysis are acid) than the cupric sulphide, and the iron is removed and $\text{Cu}_2 \text{S}$ left as the amorphous powder seen * * * * If the amount of ferric sulphate present is relatively small, copper oxide and carbonates will be formed in the lower part of the gossan and in cracks and

fissures in the underlying sulphide ores, be they original or secondary."*

The amount of copper ore thus far produced in the Black Hills is very small. On several properties where extensive work has been done, and from which few shipments have been made, the select ore heaps represent considerable value, but the chief object has been the exploitation of the properties rather than the immediate mining of ore. Occasional shipments are made for the purpose of testing the quality of the ore or to secure funds for defraying the running expenses of development work, the smelters willingly purchasing the material for fluxing purposes, but aside from this the ore has not been utilized.

IRON

Iron ore bodies of some apparent importance are found in various places within the Hills. Freight rates have prevented the extensive development of these ore bodies, and except in the case of two or three deposits almost nothing has been done toward learning their nature and extent. Small quantities of ore have been occasionally used for fluxing purposes by local smelters, and in 1893-94 one hundred sixty-five cars of ore were shipped from Nahant to the smelters of Omaha and Kansas City.

Hematite is abundant on Box Elder creek. Concerning these deposits Newton says: "On Box Elder creek a ridge some 400 feet in height is composed of a vast deposit of siliceous hematite, which was estimated to be from 800 to 1000 feet in thickness across the upturned strata. Occasional bands of almost pure specular hematite several inches in thickness are found in the mass, with frequent layers of highly crystallized micaceous hematite. The body of the ferriferous strata, however, is highly siliceous and entirely useless as an iron ore, consisting of thin strata an inch or less in thickness of specular hematite, alternating with siliceous slate or with pure white quartz, in seams or irregular masses, the whole presenting a remarkable resemblance to the siliceous banded hematite of the Huronian of the Lake Superior region. In other localities on the same creek hematites were also found in the siliceous slates, but nowhere of any practical value, because of their highly siliceous character. The slates associated with these iron deposits are commonly highly argillaceous as well as siliceous, as is indicated by their color,

*Weed, Walter Harvey. Enrichment of Mineral Veins by Later Metallic Sulphides. Bull. Geol. Soc. America, 1900, Vol. II, pp. 179-206.

texture and strong clayey odor. Similar ferruginous slates occur also on the headwaters of Rapid creek, a short distance north of the Elkhorn prairie."*

Since Newton's work in the Hills, certain deposits have been found on the Box Elder that are claimed to be fairly free from silica, and suitable for the production of iron.

Ten miles west-northwest of Rapid City, near Hat mound, a body of compact red hematite has been exposed. A partial analysis of this ore gave Fe_2O_3 , 82.05 per cent, and SiO_2 , 15.49 per cent. The ore occurs in the form of a vein enclosed by slates and quartzites, and resembles closely the better grade of Lake Superior hard ores. Two varieties are observed. One is a very dense red ore, which breaks with smooth surfaces and with distinct conchoidal fracture. The other has a less pronounced red color, is slightly less compact and breaks with a more uneven surface. Little is known of the extent of the deposit. The exposure is confined to a small rocky point near a small stream which runs northward into Bogus Jim creek about one mile above the point where the latter joins Box Elder creek.

Another property that has attracted considerable attention is Iron Mountain, situated on the Pennington-Custer county line, four miles south of Keystone, the nearest railway station. The writer has not had opportunity to see this interesting deposit, but the following description has been obtained from Mr. Samuel Scott, of Custer. The ore is in close association with granite, slate and quartzite. The course of the vein is nearly northwest-southeast and can be traced for several miles. The ore which seems to be of value extends through a length of less than one mile. On the county line the width of the vein is seven hundred feet, but much of this is not good ore. A short distance south of the line it reaches its greatest width, nine hundred fifty feet. The material is hematite, limonite, "jasper ore," and red ochre. The following analyses of the hematite ore and the jasper ore were furnished by Mr. Scott, the exact chemical formulas not being indicated:

	Hematite ore.	Jasper ore.
Iron	55.40	60.43
Silica	7.41	6.24
Phosphorus	.88	.34
Manganese	1.97	2.56
Aluminium	1.46	.36

*Report on the Geology and Resources of the Black Hills of Dakota, 1880, pp. 57 and 58.

	Hematite ore	Jasper ore
Lime	1.21	.95
Copper	.41	.10
Magnesium	47	.35
Organic and volatile matter ...	3.12	2.07
Moisture.....	9.60	10.06

The ore contains also gold and silver. A series of three hundred assays gave an average of \$3.10 in gold and one-half ounce of silver per ton.

It has been suggested that the iron may represent the gossan of a copper ledge. Much of the ore resembles gossan and considerable indications of copper have been found in the immediate vicinity but exploratory work has not progressed sufficiently to give more than a conjecture on this point.

So far as has been learned, with the exception of the shipment from Nahant already mentioned, little or no iron ore has been sent out of the Hills. Occasionally there is a demand for ochre, and recently thirty car loads of such material obtained near Rochford were ground at the Mineral Paint Works at Custer and sent to Aurora, Illinois there to be mixed with oil and prepared for market.

MANGANESE.

Manganese minerals are found widely distributed through the Hills. A few deposits have attracted attention and effort has been made to prove their economic value. The chief occurrences are in the Algonkian in Pennington and Custer counties, in the lowest thin beds of the Carboniferous near Redfern, and in the Minnelusa sandstone near Argyle. Careful analyses of samples are not available and little can be given by way of description of deposits. The most extensive exposure seems to be at Argyle. The manganese minerals, chiefly pyrolusite, are disseminated through a thirty-five foot sandstone stratum which is well exposed in a cut at this place made by a tributary of Red Canyon creek, the minerals being in places concentrated into compact layers or bunches several feet in thickness. Light shipments have been made from one or two localities, but it seems that none of the material has fully met the requirements and so far as can be learned little development work is now being done.

SILVER AND LEAD.

With the exception of the small but fairly regular amount of silver obtained from gold bullion silver is closely associated in

the Black Hills with lead. Argentiferous galena ores are found in the Galena district southeast of Deadwood, in the Carbonate district northwest of Deadwood and at Spokane, five miles southeast of Keystone. Galena is occasionally found elsewhere, particularly in the vicinity of Hayward and of Silver City, but apparently little or no contribution to the output of the galena ores has been made from other localities than the three mentioned. Cerargyrite, silver chloride, is abundant at Carbonate, particularly in the Iron Hill mine. It is also found in the Trojan and other mines near Portland. Cerussite, lead carbonate, occurs in quantity both at Carbonate and at Galena.

The earliest developments worthy of note were made at Galena, where in 1881 a smelter and a chloridizing plant were erected. These were in operation more or less continuously until 1891, the chief production being during the years 1881-84.

In 1886 silver-lead ores were found near Carbonate, the discovery of lead-carbonate on the West Virginia claim giving the camp its name. Large bodies of rich cerargyrite, galena, and cerussite were disclosed in the Iron Hill mine, and for two years or more this mine was the dominating factor in the Black Hills silver production. A smelter and a chloridizing plant were erected, but after a run of about two years they closed down and all operations ceased. During the period of activity much good ore escaped over the dump, and effort is being made at the present time to recover this material.

The Spokane mine produced considerable lead and silver during the years 1898-1900. The mine is now idle.

The character of the ore bodies in the various localities differs widely. They occur in the Algonkian in veins, in the Cambrian as shoots, and in the Carboniferous as contact deposits, the latter two graduating more or less into each other.

The ores at Spokane, at Silver City, and near Hayward are in fairly well defined quartz veins in the schists and slates. Much of the galena is coarsely crystalline, although at Silver City a cryptocrystalline variety is found. At the latter place antimony is not an uncommon associate, the mineral jamesonite, $2\text{PbS} \cdot \text{Sb}_2\text{S}_3$ occurring in some of the deposits.

At the Iron Hill mine the ore bodies occupy a nearly vertical position along a porphyry dike where it cuts through the massive limestone. Only the briefest descriptions of the mine are found in the literature, and as it is now nearly filled with water few details can be given. Well defined faulting is said to have been ob-

served and this has apparently taken place subsequent to the deposition of the ore. The ore, which has a peculiar jaspery appearance, due to the large amount of limonite present, is locally known as "liver colored rock." The jaspery nature of the ore is not distinctive, however, since much of the comparatively barren rock presents a similar appearance. Occasionally the ore is distinctly granular and retains apparently more of the original nature of the limestone of which the ore is an impregnation.

The deposits in the vicinity of Galena are within the Cambrian and are found both upon the lower quartzite and in the higher shales. The lower contact ores consist of hematite and iron carbonate, together with small quantities of lead and galena carrying gold and silver, the gold predominating where the ores carry any considerable values. The ores in the higher shales are found at various horizons. These have been the chief source of the ore in the district. Like the ores of the lower contact they consist of iron oxides with some carbonates of iron and lead, but in places where the best ore bodies have been discovered large amounts of galena have occurred. Unlike the lower contact deposits these ores contain nearly their entire value of precious metals in silver, there being rarely more than mere traces of gold.*

The ores, like the Iron Hill contact ores, are impregnations due to secretions from water which has gained access to the easily replaceable calcareous materials through numerous vertical cracks or fissures produced by the intrusion of the post Cretaceous igneous rocks, their origin being similar to that of the siliceous gold ores described elsewhere in this paper.

Almost no definite statistics are at hand concerning the output of lead from the Hills. The following table in round numbers of the annual output of silver, follows fairly closely the statistics as given by the Mineral Industry and by the Director of the Mint. The figures are evidently defective in detail, particularly in the early eighties, but the table as a whole is believed to be as nearly correct as it is possible to make it with the data at hand:

1879.	\$ 10,000	1891.	\$129,000
1880.	71,000	1892.	100,000
1881.	70,000	1893.	182,000

*Barrell, R. W. Bear Butte Mineral Formation. Black Hills Mining Review, June 18, 1900, p. 7.

1882.	175,000	1894.	106,000
1883.	150,000	1895.	206,000
1884.	150,000	1896.	302,000
1885.	100,000	1897.	299,000
1886.	425,000	1898.	197,000
1887.	540,000	1899.	209,000
1888.	100,000	1900.	129,000
1889.	135,000	1901.	140,000
1890.	129,000		
Total.			\$4,151,000

TIN.

Cassiterite was first identified in the Black Hills in 1876, by Mr. Richard Pearce, of Denver, Colorado, who detected it as stream tin in gold dust from the northern Hills. The second discovery was made on Elk gulch, in the southern Hills, in April, 1877. The material from the latter place was assayed by Theodore Vosburg, but the true nature of the bullion was first recognized by Mr. Fred J. Cross.*

These discoveries seem not to have aroused any special interest, and it was not until 1883 that the mineral attracted particular attention. In June of that year Major A. J. Simmons, of Rapid City, sent to General Gashwiler, of San Francisco, specimens of a heavy, dark colored mineral from the Etta mine, which upon examination proved to be cassiterite of excellent quality.†

At the time of the discovery of the cassiterite, the Etta mine was being exploited for mica, but this work quickly ceased and the property in 1884 coming into the possession of the Harney Peak Tin Mining, Milling and Manufacturing Company, became one of the chief centers of interest in the search for tin ore.

During this period of activity in prospecting, a vast sum of money was spent by various companies, chief among which was the Harney Peak Company already mentioned. Hundreds of mining claims were purchased, considerable exploratory work was done and several mills were erected. A few thousand pounds of metallic tin were produced, but desired results failed to appear, litigation ensued and operations ceased. Various causes have been assigned for the failure to realize better returns for the vast amount of money spent, many mining men contending that the tin is present in places in sufficient quantity to be worked with profit. The deposits possess much of scientific

*Headden, William P. Notes on the Discovery and Occurrence of Tin Ore in the Black Hills. S. D., Col. Sci. Soc. Proc., Vol III., Pt. III, pp. 347-350.

†Blake, W. P. Tin. Min. Res. of the United States, 1883-84, U. S. G. S., p. 602.

interest, and in view of their possible future value, the following brief description is given:

The cassiterite is found in place and as stream tin in two districts, namely the Harney Peak district in Pennington and Custer counties, and the Nigger Hill district in the northwestern part of the Hills, near the Wyoming-South Dakota line. The rock containing the cassiterite in place is an extremely coarse granite, known as pegmatite, the pegmatite occurring in the form of dikes. These dikes cut the country rock in every direction, although generally in accurate or approximate conformity with the schistosity when occurring in metamorphic rocks. They range in size up to many yards in width and hundreds of yards in length. When cutting through the country granite, the dikes generally show a depression, due to the more rapid weathering of the pegmatite, but in areas of schistose rocks its relative rate of weathering is usually slower than the enclosing rocks, hence is often seen in such places as a projecting mass, which not infrequently can be traced for considerable distances by the topography alone.

The tin occurs almost only in the form of cassiterite, SnO_2 . Cupro-cassiterite occurs at the Etta, stannite has been identified, and a peculiar hydrous oxide is occasionally found, but these aside from their scientific interest are of no value. The cassiterite is found as a constituent mineral of the pegmatite, in crystals or masses of all sizes up to many pounds weight. Some of the heavier masses at the Etta weighed fifty or sixty pounds, and lumps of three or four pounds were common.*

Many claims afford crystals weighing several ounces, and in some localities specimens suitable for gems have been found, but most of the material in all of the mines comes in finer particles. The mineral occurs chiefly in a feldspar-muscovite aggregate but is occasionally found in a quartz-muscovite aggregate or in quartz alone. The following mineral associates are listed as having been found:

Albite oligoclase.	Loellingite,
Almandite,	Melanite,
Andalusite,	Microcline.
Apatite,	Molybdenite,
Arsenopyrite,	Monazite,

*Blake, W. P. Tin. Min. Res. of the United States, 1883-84, U. S. G. S., p. 607.

Autunite,	Muscovite,
Barite,	Olivenite,
Beryl,	Orthoclase,
Biotite,	Petalite,
Bismuth,	Quartz,
Columbite,	Rutile,
Corundum,	Scheelite,
Cupro-cassit erite,	Scorodite,
Epidote,	Sphene,
Galena,	Spinel,
Graphite,	Spodumene,
Griphite,	Stannite,
Grossularite,	Tantalite,
Heterosite,	Tourmaline,
Ilmenite,	Triphylite,
Lépidolite,	Triplite,
Leucopyrite,	Wolframite,
Liebnerite,	Zircon.

A few of these minerals deserve special mention. Spodumene occurs in extremely large crystals, and being of some economic importance on account of its lithia content, receives a more extended notice elsewhere in this paper. The beryl, the tourmaline, and the columbite are also noteworthy. Beryls one foot or more in length are not uncommon, and one crystal was found which measured fourteen inches in diameter. Tourmaline is particularly abundant, occurring in well defined crystals and in the massive state, the crystals being sometimes six inches or more in diameter. The columbite is found less widely distributed, but well developed, and in the Bob Ingersoll mine one mass obtained, said to be the largest columbite crystal known to mineralogical science, weighed approximately one ton.* Cupro-cassiterite and the variety of triplite known as griphite are found only in the Black Hills, the first mineral having been described by Mr. Titus Ulke,† and the second by Professor W. P. Headden‡

The cassiterite runs high in metallic tin, as indicated by the following analyses:§

*Blake, William P. Columbite in the Black Hills of Dakota. *Am. Jour. Sci.* 3d ser., Vol. XXVIII, pp 340-341.

†Ulke, Titus. A New Tin Mineral in the Black Hills. *Am. Inst. Min. Eng. Trans.*, Vol. XXI., pp. 240-241.

‡Headden, William P. A New Phosphate mineral from the Black Hills of South Dakota, *Am. Jour. Sci.*, 3d ser., Vol. XLI., pp. 415-417.

§Carpenter, Franklin R. The Mineral Resources of the Black Hills, their Character, Occurrence and Extent. *Dak. Sch. Mines, Prelim. Rep.*, 1888, pp. 141-142.



PHOTOGRAPH BY O'HARRA, 1901.

THE ETTA MINE, NEAR KEYSTONE.

	Stannic oxide. Per cent.	Metallic tin. Per cent.
Occidental mine.....	96.42	75.86
Tin Mountain mine.....	97.5	76.7
First Find mine.....	94.7	74.5
Nigger Hill stream tin.....	92.6	72.84
Nigger Hill stream tin.. .	93.	73.21
Southern Hills stream tin.....	92.8	73

Professor Carpenter calls attention to the fact that while the stream tin is clearly derived from the tin veins by disintegration yet the vein tin carries a higher percentage of the metal than does the stream tin. This is peculiar, as alluvial tin is generally purer than lode tin because during the process of disintegration and transportation the more soluble impurities are removed. Heavy minerals other than cassiterite such as columbite, tantalite, etcetera, are found in the stream gravels of the Black Hills and possibly these aid in lowering the percentage of tin.

The analyses given indicate the excellent character of the cassiterite, and no one acquainted with the tin deposits can doubt their great extent, hence the chief uncertainty is whether or not the mineral occurs sufficiently concentrated in any of the deposits to yield a continuous supply of ore of high enough grade to be profitably worked. High grade samples can be readily obtained from many localities but percentages in such cases have little value from an economic standpoint. Of the various reports and assays that have been made on the tin properties the following estimates and results will best serve our purpose:*

RESULTS OF ASSAYS OF HARNEY PEAK TIN ORES.

Name of Assayer.	Av. number of pounds of blk tin per long ton of 2,240 pounds of r'ck	Pounds of White metal yield per ton of 2,240 tbs.	Per cent of tin.
Prof. W. P. Blake..	72.8	36.4	1.625
E. N. Riotte....	67.2		
Prof. H. O. Hoffman.... . . .	57.54	39.2	1.746
Prof. C. M. Vincent (Estimate).	30.	22.5	1.
Prof. C. M. Vincent (Select sam)		38.8	1.732
Capt. Josiah Thomas (Estimate)	40	29.2	1.3

*Rolker, Charles M. The Production of Tin in Various Parts of the World. Sixteenth Ann. Rept., U. S. G. S., Min. Res. pt. III, p. 533.

Professor Carpenter estimates that in sorting the ore if only such rock is saved as will carry ten pounds or more of cassiterite to the ton the average for the Black Hills tin ores will probably reach two per cent. Many individuals consider this estimate too high while others think it too low.

During the year 1892 five thousand tons of ore were milled by the Harney Peak company, but the concentrates collected were estimated to yield only one-fourth of one per cent of metallic tin per ton of rock crushed. Loss in concentration incidental to the use of new machinery doubtless influenced the result, but it is claimed that the loss was much greater than it should have been. The ore for this run, which occupied about two months, was obtained from many claims, and apparently little or no account was kept of the relative value of the ores from the various places.

In the minds of many mining men the failure to profitably work the tin deposits in the past was due in great part to unwise management and not to the low grade of the ore. In view of this belief some effort is now being made to reopen old mines and possibly by careful avoidance of extravagant methods some of the more favorable deposits may yet be made to yield fair returns.

The total amount of metallic tin that has been produced from Black Hills ores is indefinite but small. In 1884 several hundred pounds were produced, in 1891 four hundred forty-seven pounds and in 1893 nearly nine thousand pounds. Previous to 1893 ore and concentrates including stream tin, the latter chiefly from the Nigger Hill district, were shipped to England sufficient to produce perhaps two or three tons of the metal. Considerable stream tin has been shipped to England from the Nigger Hill district during the past few years so that the total product of metallic tin from the Black Hills has possibly reached 50,000 pounds. At the present time the placer miners of the Nigger Hill district have a number of tons of stream tin in their possession, and Mr. M. R. Hydcliff, of Bear gulch, has more than one hundred pounds of the metal which he has obtained from stream tin by such simple means as the assayer with small laboratory is able to utilize. One specimen of nearly pure stream tin (cassiterite) found by Mr. Hydcliff in Bear gulch and now in his possession weighs eighty ounces.

TUNGSTEN.

Tungsten of commercial importance was discovered near Lead in 1899.

In the early days of the tin excitement in the Black Hills wolframite, FeWO_4 , was identified at various localities in the Harney Peak and Nigger Hill granite districts but the deposits were not considered important, and no effort was made to prospect for the mineral. Since the discovery of the deposits in the northern Hills special search has been made for commercially valuable deposits in the granite areas but with the possible exception of one or two properties in the Harney Peak region the search thus far has been fruitless.

The existence in the refractory siliceous gold ores near Lead and on Yellow creek of a heavy mineral locally called "black iron" was known for several years prior to 1899. This black material when sufficiently auriferous to be of value as a gold ore was sent to the smelter and treated for its gold content. When low in gold values, which was frequently the case, it was thrown out as worthless material, and thus considerable quantities gradually accumulated in the waste heaps of the mines where it occurs.

Mr O. A. Reitz, a teacher in the Lead High school, became interested in the mineral on account of its high specific gravity, and in January, 1899, secured some of the material for examination. A few simple tests proved the mineral to be wolframite. Manufacturers of tungsten steel immediately became interested in the region and various small sales of ore were quickly made at prices ranging from \$100 to \$250 a ton, the per centage of tungstic acid in these shipments varying from 35 to 54 per cent.

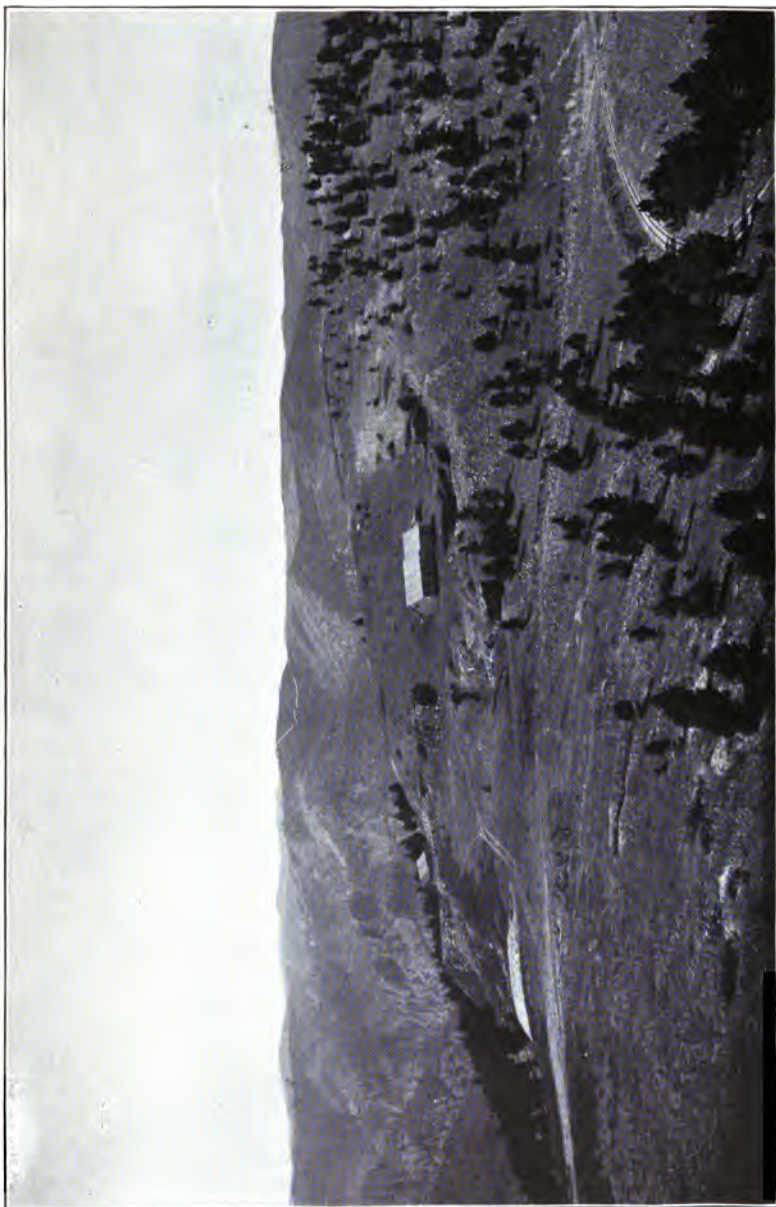
Only two localities have thus far afforded ore in any appreciable quantity. One lies just north of Lead. The other is situated about two and one-half miles south-southeast of Lead. The deposits in both localities are intimately associated with the Cambrian siliceous ores. Much of the hill to the north of Lead forming the divide between Gold Run and Deadwood gulches is capped by Cambrian rocks, and it is near the gently rolling crest of the western portion of this hill that the most extensive wolframite deposits have been found. These are known as the Lead deposits, and the following properties have contributed to the output: Durango, Harrison, Sula, Hidden Fortune, plate 20, Reddy and Golden Crown. South-southeast of Lead on the

ridge between Yellow and Whitewood creeks there is a northerly projecting tongue of Cambrian rocks in which wolframite occurs in considerable abundance, and the deposits here are known as the Yellow Creek deposits. The Wasp No. 2 and the Two Strike mines have been the chief producers. A straight line drawn through the two wolframite areas follows closely the schistosity of the upturned metamorphic rocks below, and the open cuts of the Homestake mine which are situated immediately east of the Lead deposits lie in a line nearly parallel to that connecting the wolframite areas.

The wolframite bodies are quite irregular in shape although partaking to some extent of the form or outline of the flat gold ore chutes with which they occur. Their thickness is rarely more than two feet and the concentrated portions are generally only a few inches thick. Their lateral extent occasionally reaches thirty feet or more. Irving calls attention to the fact that the wolframite should be considered in the nature of a basic phase of the siliceous gold ores rather than as a separate and distinct deposit since it always occurs in intimate association with them.*

The wolframite is dense, black, granular, and shows good crystal faces only when the mineral has formed on the surface of cavities. Crystal druses of yellowish and green scheelite, CaWO_4 , are common. Barite, BaSO_4 , is frequently present, sometimes in great abundance in large white tabular crystals. Stibnite, Sb_2S_3 , in long slender crystals has been found in the leaner ores of Yellow creek. The last two minerals have been found however in siliceous gold ores elsewhere where no wolframite has been detected hence possibly have little or no direct connection with the deposition of the wolframite. The wolframite from the Harney Peak and Nigger Hill districts is distinctly crystalline and is easily distinguished from the ore of Lead and Yellow creek. It occurs in pegmatitic granite in close association with quartz. The mineral is unevenly distributed throughout the pegmatite and occurs in bunches or masses sometimes of several pounds weight. The percentage of tungstic trioxide is high as is also manganese oxide, the former being given as 74.82 per cent and the latter at 19.95 per cent.

*Irving, J. D. Some Recently Exploited Deposits of Wolframite in the Black Hills of South Dakota. A. I. M. E. Trans. Pamphlet edition, Feb., 1901.



PHOTOGRAPH BY O'HARRA, 1901.

THE HIDDEN FORTUNE MINE, NEAR LEAD.

The following analysis of Yellow Creek wolframite is by Mr. W. F. Hillebrand of the United States Geological Survey.† The specimens for analysis were obtained at the Two Strike mine:

Si O ₂	12.87
W O ₃	61.50
Fe ₂ O ₃	3.85
Fe O	9.18
Al ₂ O ₃	0.52
Mn O	8.21
Ca O	0.93
Sr O	0.02
Ba O	0.04
K ₂ O+Na ₂ O+Li ₂ O	0.08
H ₂ O*	0.20
H ₂ O**	0.87
As ₂ O ₅	1.25
P ₂ O ₅	0.12
V ₂ O ₅	Trace
S or SO ₃	Trace

99.64

Assays:—Gold, 0.05 oz. per ton; silver, 0.25 oz. per ton.

Extremely minute traces of Mg, Zn, Cu, Sb, and Sn were also found.

*Up to 105° C. **Above 105° C.

Concerning the mode of formation of the deposits and the probable source of material, I quote at length from Mr. Irving: "That they are formed through the gradual replacement of the country rock by wolframite, seems to the writer to be clearly indicated by the character of the ore, the nature of the beds in which it is found, and the metasomatic origin of the ores with which it is inseparably connected. First, the wolframite itself is filled with cavities of irregular form and distribution, such as are almost always to be observed in ores formed by replacement, where the aggregate volume of the mineral introduced is smaller than that of the original rock; secondly, the beds in which the ore occurs, are composed chiefly of magnesian limestone, often

†Irving, J. D. Some Recently Exploited Deposits of Wolframite in the Black Hills of South Dakota, A. I. M. E. Trans. Pamphlet Edition, Feb., 1901.

quite impure, it is true, but of a prevailingly soluble character; thirdly. the wolframite is an integral part of the shoots of siliceous gold ore, the metasomatic origin of which has been conclusively proved by careful microscopic study.

"As regards the source from which the tungsten minerals have been derived, no positive conclusion can be formed; but the relation of the deposits to the geology and to the other ore bodies of the neighborhood seems to furnish some evidence as to their derivation. They are found at two rather widely separated localities on the west side of the outcrop of the Homestake ore body. Along this line there has taken place, first, the heavy mineralization of the Algonkian rocks, which has produced that well-known ore body; secondly, the mineralization of the Cambrian above, resulting in the formation of siliceous gold ores, which are richer and contain a more varied assortment of secondary minerals than ores of similar character away from the Homestake lode; and, thirdly, the formation of the wolframite ores themselves. It seems, then, that the line of strike of the Homestake lode is also a line along which mineralization has been both varied and unusually intense. During this extensive mineralization, the circulation of waters capable of dissolving the metallic contents of the surrounding rocks, must have been active. That these waters were, in the case of the siliceous ores, and hence in the case of the wolframite, ascending waters, is proved by the concentration of these deposits beneath impervious beds. It is therefore not unreasonable to suppose that if wolframite occurred in the Algonkian rocks at some point below the deposits now worked, just as it occurs in its normal relations at other points within the Hills, the action of ascending thermal waters upon this material should have given rise to the mineral-bearing solutions which carried the wolframite up to its present position, and, there encountering rock sufficiently soluble to admit of metasomatic interchange, should have redeposited their metallic contents.

"If this be true, it may be said that there are two distinct but genetically related types of wolframite deposit in this region: (1). That which characteristically occurs in the granitic and related rocks of the Algonkian, and is comparable with the greater number of such deposits from other parts of the world. This is instanced by the wolframite from Nigger Hill and the Etta tin mines in the southern Black Hills. It may be termed a 'primary' deposit. (2). That which has been formed by the solution of

bodies of the first type, and a metasomatic redeposition of the material in stratigraphically higher beds. This may be termed 'secondary,' '*

The ore is low grade, demanding hand picking or machine concentration. Most of the material sold has been concentrated sufficiently to give from 38 per cent to 50 percent tungstic acid. Of the producing mines the Durango has placed the largest amount upon the market, while the Harrison has at the present time the largest amount immediately available. The price has varied from less than \$100 to more than \$200 a ton, the earlier shipments commanding the higher prices. The total amount marketed will approximate 140 tons. Practically all of this was sold during the years 1899 and 1900.

GRAPHITE

Graphitic slates are abundant in many parts of the Hills, and in not a few places the percentage of graphite is sufficiently high to arouse some interest in the economic possibilities of the deposits. Considerable prospecting has been done in the central Hills, particularly near Custer and Rochford. Recently sixteen car loads of the mineral were ground at the Mineral Paint Works in Custer, and shipped to Aurora, Illinois, for final preparation for market.

MICA.

The earliest explorations for mica in the Black Hills were made in 1879, the McMacken mine, plate, 21 near Custer, being the first property upon which much work was done. Up to July 1, 1884, it had produced 45,000 pounds of cut mica, at an average price of \$3 a pound, or a total of \$135,000. The New York, the Lost Bonanza, and the Climax mines were opened only a little later, and up to July 1, 1884, had produced as follows: New York, 5,700 pounds, value \$19,950; Lost Bonanza, 26,000 pounds, value \$113,100; Climax 7,940 pounds, value \$34,539. In addition to these mines, other smaller mines produced 40,000. The total product for the year 1884 amounted to 18,150 pounds, worth \$63,525. The mines which contributed to this output were the Climax, the Lost Bonanza, the White Spar, the Eureka, the New York, the Last Chance, the Warren, the Keystone, the Window Light, the Millard, and the Nellie, of Custer county. In addition

*Irving, J. D. Some Recently Exploited Deposits of Wolframite in the Black Hills of South Dakota. A. I. M. E. Trans., Pamphlet Edition, Feb., 1901.

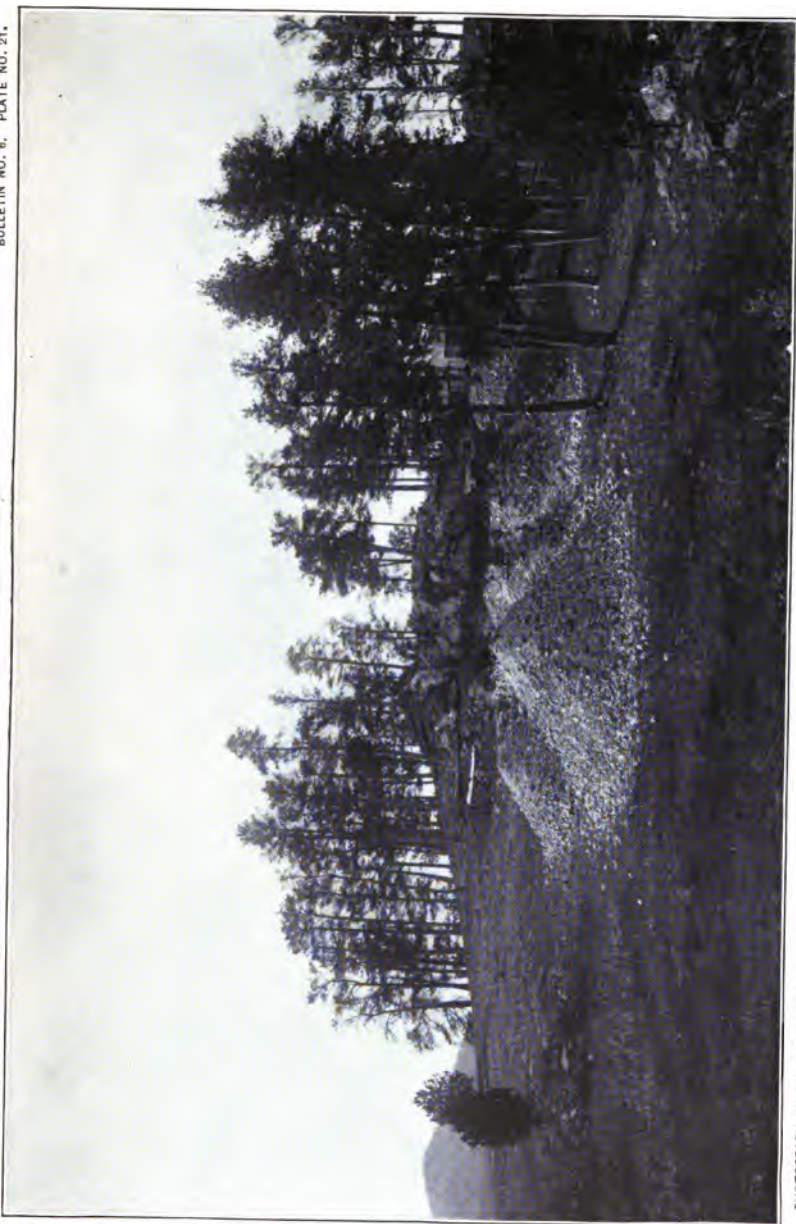
to these a small group of mines near Keystone, in Pennington county, including the Emma, the Peerless, the Celia, and the Alice, produced some mica, the amount not known.*

With the output of 1884, most of the mines practically ceased operating, the work during subsequent years until 1899 consisting of scarcely more than such development work as is necessary to hold claims. During this period of quiescence the output so far as I am able to learn was as follows: 1886, 600 pounds; 1896, 8,100 pounds; 1898, 990 pounds. In 1899 and 1900 the output greatly increased. During the latter year scrap mica was shipped for the first time, all of the earlier product having been sold in the form of sheets. The output in 1899 was 20,299 pounds, valued at \$18,000. In 1900 the sheet mica output reached the unprecedented amount of 65,000 pounds, value \$45,000, while the production of scrap mica amounted to 222 tons, worth \$1,554. The New York, the Lost Bonanza, and the Monarch mines were the chief producers, most of the output going to the Chicago and the New York markets. During 1901 approximately 200,000 pounds were shipped, but the proportion of sheet and scrap was not learned. The entire production came from the Crown (McMackin) mine and the New York mine.

The mica is found in pegmatite dikes, which occur in great abundance in the granite region of Pennington and Custer counties. The dike material is made up chiefly of coarsely crystalline quartz, feldspar and mica, the masses of quartz and feldspar being not infrequently developed in pieces of many pounds weight, and mica books two feet or more in diameter are said to have been mined. For a fuller description of these dikes the reader is referred to the tin deposits described elsewhere in this paper.

Many of the dikes do not contain large mica books in sufficient amount to make them profitable producers, but all have the mica present to a greater or less extent. The books sometimes show much regularity of arrangement with reference to the hanging wall and the foot wall, the books being situated near the wall, and oriented in all planes perpendicular to it. This arrangement is particularly noticeable in the New York mine, five miles west of Custer, where the pegmatite dike has a thickness of forty feet, and in which most of the workable mica lies within a few feet of the outer walls, the side next the

*Clarke, F. W. Mica. Min. Res. of the United States, 1883-84. U. S. G. S., pp. 909-910.



PHOTOGRAPH BY O'HARRA, 1901.

THE MACMACKIN MICA MINE, NEAR CUSTER.

foot wall having produced the larger quantity. In many mines the mica is irregularly distributed within the dike and when such is the case much worthless gangue must be removed, and exploratory work is necessarily carried on with some degree of uncertainty. Thus it is clear that the percentage of mica in given portions of the dike varies widely. The mica occasionally amounts to eight or ten per cent or the total mass of pegmatite mined, but it is generally much less.

In the early days, when mining was active, stove mica was the chief product, but now most of the material is sold for use in electrical work. Much of the scrap mica formerly considered as waste material, has been sold to be ground for lubricating purposes.

Concerning the probable future development of the Black Hills mica industry, I cannot do better than to quote from Professor J. A. Holmes, who has made a study of the deposits: "There are undoubtedly large quantities of mica which, with fair prices and modern mining methods, can be profitably taken from the McMackin, Climax, New York, Lost Bonanza, White Star, and a dozen other mines in that district. Besides these there are numerous other large, unopened dikes which exhibit on the surface as good prospects as did originally many of those which have been more or less developed. The mica in this district is, as a rule, good in color and free from iron specks. Its greatest defect is the considerable extent to which the blocks or 'books' of mica are ruled and wedge-shaped, making the sheets smaller and the splitting defective. But notwithstanding these defects, there are still to be found in Custer and Pennington counties large quantities of high grade mica. Indeed, it may be fairly claimed that mica mining in the Black Hills region is yet in its infancy."*

SPODUMENE.

Spodumene, $\text{LiAl}(\text{SiO}_3)_2$, has recently achieved commercial importance in the Black Hills and considerable local activity has been shown in the development of the industry. The deposits are all found in the Harney Peak district in Custer and Pennington counties.

Attention was first attracted to the mineral during the tin mining activity, at which time its occurrence was observed in several localities. The most noted of these is the Etta mine,

*Holmes, J. A. Mica Deposits in the United States. Min. Res. of the United States, 1898, U. S. G. S., part VI, cont. pp. 705-706

plate 19, at which place exposures have been made of some of the largest crystals known to this mineral species. Owing to their extreme size and irregularity of position mining operations seldom disclose complete lengths, but Professor Blake mentions one showing in the sides of a drift for thirty-six feet without break or deflection.* In diameter they range up to four feet or more. Crystals three feet in diameter are not uncommon, and those having diameter of as much as two feet are abundant. Mr Samuel Scott informs me of one crystal on property adjoining the townsite of Custer that has been exposed for a distance of ten feet and which measures in cross section five feet four inches by four feet nine inches.

• The crystals or "logs" as they are more generally called by the local miners lie imbedded in the pegmatite matrix already referred to under the subject of tin, and are intimately associated with the tin-bearing material. They apparently lie in all possible positions with reference to each other, sometimes considerably separated, sometimes segregated in bunches but more often evenly distributed through the pegmatite in great profusion, plate 22

The mineral associates of the spodumene in the Black Hills are practically the same as those given elsewhere in this paper for cassiterite and, with the possible exception of two or three unimportant minerals there mentioned, were contemporaneous. In reference to their origin Prof. Blake says: "All these minerals appear to have crystallized out of a semifluid or pasty magma in which the elements were free to arrange themselves from one side of the dike to the other, and to separate out by slow crystallization. There is a banded arrangement, sometimes very distinct, and again obscure; but different from the banded structure seen in fissure veins, where there appears to have been an open fissure subsequently filled gradually by the flow of water depositing layer after layer upon each side of the fissure until it became filled. In the dikes the rude structure seems rather to be due to the crystallization of the magma which filled the space between the walls, the difference of the structure of the portion next to the walls being the result possibly of difference of pressure or temperature, or the different temperature or conditions governing the formation of one compound after another.

*Blake, W. P. Tin Min., Res. of the United States, 1883-84, U. S. G. S., p. 608.



PHOTOGRAPH BY O'HARRA, 1901

SPODUMENE CRYSTALS, ETTA MINE, NEAR KEYSTONE.

Thus in the great dike or injected mass of the Etta mine, mica is generally found next to the walls, so also at the Ingersoll, while feldspar and quartz fill the center; but this central mass is penetrated in every direction by the enormous crystals of spodumene, the cassiterite being disseminated in bunches, but particularly in the included masses of albitic greisen which seem to have filled the spaces left after the other minerals had assumed their form ""*

Attention seems to have been first directed in 1895 to the possible economic value of the spodumene. During the summer of that year a lithium analysis of the mineral was made at the South Dakota School of Mines and Dr. M'Gillicuddy, then Dean of the School, endeavored to have the mineral investigated by reliable chemical manufacturers. Little or no active attention was given to the subject until three years later when during the latter part of 1898 one car load of thirty tons of the spodumene was mined at the Etta for experimental purposes under the direction of Messrs. Reimbold and Company of Omaha. During the following year, 1899, the Etta produced 500 tons and in 1900 approximately 700 tons. A considerable proportion, however, of the latter amount remained last year at the mine ready for shipment and active operations for the time being have ceased.

Subsequent to the earlier shipments from the Etta other properties were developed and various amounts have been mined. Several of these properties show large crystals, especially the Wood mine, two and one-half miles east of Keystone; the Boomerang, one mile southeast of Keystone; the Sunday Fraction immediately adjoining the Boomerang; and the Palmer gulch, five miles southeast of Hill City. Each of these has produced about 200 tons. In addition to these properties spodumene has been found on the Grand View claims situated adjoining the Boomerang and the Sunday Fraction; on the Tin Mountain vein, six miles west of Custer; on the veins of the Telegraph Group; and on properties near Custer and Glendale. It is doubtless present also in greater or less abundance on many claims where little attention has been paid to its observation.

The value of the mineral varies with the lithia content. The samples analyzed at the School of Mines carried 6.16 per cent lithia, and this is perhaps a fair average. The chief use of

*Blake, W. P. Tin. Min. Res. of the United States, 1883-84, U. S. G. S., pp. 596-597.

the product is in the manufacture of lithium salts, chiefly lithium carbonate, for the preparation of lithia water. Most lithium salts are obtained from lepidolite, nearly all of the supply for the United States being imported from Europe. The chemical processes are complex and rather carefully guarded, and it has been found difficult to develop methods for extracting the lithia content from the spodumene with profit. For this reason there has been practically no regular price offered for the mineral, most of the material having been secured by direct purchase of claims or by royalty arrangement. The total cost per ton of most of the material delivered on the car at Keystone has been between \$20 and \$25. A total amount of about 1,600 tons has been shipped.

MISCELLANEOUS MINERALS.

Of the many minerals occurring within the Hills a few in addition to those already described deserve mention here.

Antimony in the form of jamesonite is found in some quantity near Silver City and Rochford. The extent and value of the deposits have not been determined.

Bismuth is occasionally found in the southern Hills, and a few years ago some exploratory work was done in this connection near Hayward. The efforts failed to reveal good material in quantity, and after a short time operations ceased.

In the early days of Black Hills mining not a little interest was taken in the occurrence of cinnabar on Victoria creek a few miles above Rapid City. Later the mineral was found also near Pactola and Rochford. Considerable prospecting was done but no deposits of importance were found and the search was abandoned.

Nickel is said to occur in many places. Pyrrhotite is found throughout the Algonkian area and Professor Carpenter states that in practically every instance the Pyrrhotite carries nickel. More recent investigation has thrown doubt upon the general application of this statement, and in the absence of careful analyses little can be said in regard to the possibilities of the metal within the Hills.

Uranium minerals have been observed in various places, particularly in the Poisoned Ox mine near Pactola, and in the Davier mine on Anna creek near Portland. Uranium is also reported as occurring near Carbonate. At the Poisoned Ox mine the mineral occurs with copper in slates. In the Anna

creek property it is intimately associated with porphyry. At the latter place effort has been made to obtain the mineral in commercial quantities, but as yet success has not been attained.

Rarer minerals of beauty and interest but of little or no value in metallurgical processes occur throughout the Hills. To local dealers they are a constant source of profit but their description does not come within the purpose of this paper.

RESUME OF MINERAL PRODUCTION.

In the table given below the writer has endeavored to summarize as carefully as possible the total mineral production of the Black Hills. From what has been given on previous pages it may be inferred that the statistics of output of gold, silver, tin, tungsten, mica, and spodumene are fairly complete and approximately accurate. The estimate for lead is quite uncertain and may need correction. The output given for copper, iron, maganese, graphite, and miscellaneous minerals is also uncertain. Perhaps least is known of the total production of structural materials, lime for fluxing purposes, abrasive materials, etc., hence the figures given under the head of Structural Materials, etc., should be considered only a rough estimate made with little available data. (See footnote, page 9.)

TOTAL MINERAL PRODUCTION OF THE BLACK HILLS, 1875-1901.

Gold	\$100,210,000
Silver	4,154,000
Lead.....	400,000
Copper, Iron, Manganese, Graphite, etc....	40,000
Tin	10,000
Tungsten.....	25,000
Mica	600,000
Spodumene.....	40,000
Structural Materials, etc.....	3,600,000
Total..	\$109,079,000

CONCLUSION.

The mining interests of the Black Hills were never in a more satisfactory condition than at the present time. For several years the mineral output has been steadily and rapidly increasing. The mining problems have always been fairly simple, and metallurgical difficulties which long hindered the development of much good property have been largely overcome.

The Homestake, the great mine of the Hills, has never before dropped so many stamps nor produced so much gold. Among the siliceous deposits high grade ores continue to be

found, nearly all of the developed mines are regularly producing, and at no previous time has it been possible to utilize so much of the low grade ores. Mines are being profitably opened on mineral deposits which hitherto have received little or no attention, and older mines once abandoned are being rejuvenated. Mills and metallurgical plants judiciously constructed and backed by worthy quantities of suitable ore are rapidly multiplying and wise management and modern methods prevail. Good yellow pine, *Pinus ponderosa*, suitable for mine timbers, buildings and fuel, is in great abundance, various coal deposits are convenient, and water is generally plentiful. Excellent detailed topographic maps prepared by the United States Geological Survey are available, a bullion depository government assay office has been established at Deadwood, the railroads are advancing in harmony with the needs of the region, and all classes of mineral development give assurance of stability and growth.

INDEX.

A		PAGE
Albite	67	
Algonkian	12, 14	
Alice mica mine	15, 21, 31, 63, 74	80
Almandite	76	
Alpha-Omega gold mine	67	
Altitude	32	
Amalgamating stamp mills	12	
American Express gold mine	55	
Amphibolites	39	
ANALYSES:	12, 30, 31	
Cement gold	35	
Homestake gold	35	
Iron ore	62	
Lime-siliceous ore	47	
Placer gold	53	
Siliceous ores	44	
Spodumene	79	
Tin ore	69	
Wolframite	73	
Andalusite	67	
Ankeny, O. P.	46	
Anna creek	80	
Antimony	43, 80	
Apatite	67	
Argyle	63	
Arrastre	28, 32, 45	
Arsenopyrite	30, 67	
Assay office	82	
Assays of tin ores	69	
Atlantic gold mine	22	
Aurum, The	56	
Autunite	68	
B		PAGE
Bald Mountain	20, 37, 55	
Balmoral flat	47	
Balmoral vertical	48	
Barite	43, 68, 72	
Barrel, R. W.	65	
Basic eruptions	15, 31	
Battle creek	50, 51, 52, 53	
Bear gulch	38, 52, 53, 54, 70	
Beaver creek	38	
Bell, William	54	
Belle Fourche river	14	
Aztec	40	
Beryl	68	
Benton group	13	
Beulah shale	13	
Big Bonanza gold mine	40	
Bion pyrite vein	25	
Biotite	68	
Bismuth	68, 80	
Black Hills copper company	57, 58	
Black Hills development com- pany	30	
Black Hills gold extraction company	46	
Black Hills placer mining com- pany	51	
Blacktail gulch	19, 36, 52	
Blake, W. P.	66, 68, 69, 78	
Blanket formation	41	
Blatchford, Mr.	43	
Blue Lead copper property	57, 58, 59	
Blue siliceous ore	42	
Bob Ingersoll mine	68	
Bobtail gulch	34, 52	
Bogus Jim creek	58, 62	
Bonanzas	59	
Boomerang spodumene prop- erty	79	
Box Elder	52, 58, 61, 62	
Breccias	21, 25	
British American copper prop- erty	58	
Buffalo Gap	20	
Bullion gold mine	27	
Burlington R. R.	20	
Buxton gold mine	42	
Buxton Mining Company	46	
C		PAGE
Calcium	43	
Caledonia	29	
Cambrian	14, 15, 21, 31, 32	
33, 35 36, 37, 39, 65, 71, 72, 74		
Carbonate	55, 64, 80	
Carboniferous	12, 14	
15, 21, 31, 46, 63		
Carlile formation	13	
Carpenter, F. R.	27, 30	
31, 54, 68, 70, 80		

	PAGE		PAGE
Carr, Lee and Charles.....	54	Deadwood and Delaware smelter	55
Cassiterite .. 54, 66, 70	78	D & D smelting company....	46
Castle creek..... 18, 50,	53	Deadwood Standard mining company	48
Celia mica mine.....	76	Decorah gold mine..... 39,	40
Cement ores..... 32-37,	57	Delaware shaft.....	40
Centennial gulch.....	54	Depth of shafts..... 23, 30,	40
Central	29, 31	Devereux, W. B.	34, 35
Cerargyrite.....	64	Devonian.....	15
Cerussite	64	Dikes..... 21, 25, 37, 67,	76
Chevenne river..... 12,	14	Dioritic rocks.....	25
Chief of the Hills gold mine..	32	Discovery claim..... 19,	53
Chilkoot gold mine	23	Discovery of gold.....	16
Chilkoot district.....	24	Dovle vertical.....	48
Chloridizing plant.....	64	Drainage	14
Chlorination process..... 46,	55	Dry diggings.....	51
Cinnabar	80	Ducktown copper deposits ..	59
Cleopatra gold mine..... 39,	40	Durango gold mine..... 71,	75
41, 42, 48,	50		
Climax mica mine	75, 77		
Columbite	54, 68, 69		
Conglomerate ores..... 19, 21,	32 - 37		
Corundum	68		
Crystals, size of..... 68,	78		
Copper..... 20, 57 - 61			
Copper Castle property	58		
Copper Cliff property.....	58		
Copper Glance property.....	58		
Copper Reef property	58		
Cretaceous..... 12, 13,	15		
Cross, Fred J.....	66		
Crown mica mine	76		
Crown Hill..... 20, 36,	37, 39		
Cupro-cassiterite	67, 68		
Custer	16, 17, 21, 22, 62, 63		
75, 76, 78,	79		
Custer county	21, 22		
25, 62, 63, 75, 76,	78, 79		
Custer, General, expedition of	16, 17		
Custer park	16, 19		
Cyaniding	55		
Cyanide lixiviation.....	46		
Cyanide plants..... 29, 30,	55, 56		
D			
Dacites	12		
Dacy drill hole	39		
Dacy flat	47, 48, 50		
Dacy shaft.....	39		
Dacy vertical.....	48		
Dakota sandstone.....	13		
Darton, N. H..... 12,	14		
Davies mine.....	80		
Deadwood, city of..... 14,	20		
27, 32, 46, 55,	58, 64		
Deadwood formation	14, 33		
Deadwood gulch 19, 32, 34, 36,	54, 71		
Deadwood mill.....	29		
Deadwood placers..... 32, 36,	52		
		E	
		Early prospecting..... 16, 17,	18
		Elephas primigenius	54
		Elk creek..... 52,	58
		Elk gulch.....	66
		Elkhorn prairie.....	62
		Emma mica mine	76
		Empire gold mine.....	45
		Englewood limestone.....	14
		Enos, Mr	28
		Epidote	68
		Estrella del Norte company	51
		Etta tin mine .. 66, 67, 74,	77
		Eureka mica mine.....	75
		Exploratory work, method of	42
		F	
		Fantail gulch..... 40,	46
		Father de Smet mill.....	29
		Faulting in ore bodies.....	40
		F., E. & M. V. R. R..... 19,	20
		Fissure veins..... 21,	22
		Flumes.....	51
		Fluorite	43, 48
		Fluxes..... 25, 57,	61
		Folger gold mine	45
		Fossil placers.....	34
		Fossils in placer deposits.....	54
		Fox Hills formation	13
		Frank, Portgee.....	53
		Free milling ores.....	46
		French creek..... 16, 17, 18,	21, 52
		Fuson formation.....	13
		G	
		Galena district 25, 37, 41,	64, 65
		Galena, mineral..... 23, 64,	68
		Galena, town of..... 20, 37,	64

PAGE	PAGE
Gardner, Chase & Co..... 32	Highland mine..... 28
Garnets..... 54	Highland mill..... 29
Gashweiler, General..... 66	Hill City..... 20, 22, 58, 79
Gayville..... 32, 36	Hillebrand, W. E..... 73
Gems..... 67	Historical Review..... 16 - 20
Geology of Black Hills..... 11	Hoffman, H. O..... 69
Generalized section..... 13	Hogback ridges..... 12
Giant claim..... 28	Holmes, J. A..... 77
Gillespie, David..... 54	Holy Fright copper property..... 58
Gilmore pyrite vein..... 25	Holy Terror mine..... 22, 23, 24
Glendale..... 79	Homestake belt, 19, 27, 29, 34, 35, 57
Gold..... 11, 16, 17, 20-57, 65	Homestake company..... 20
Gold, classification of ores..... 20	Homestake open cuts..... 30
Gold free in Cambrian..... 36	Homestake lode..... 74
Golden Crown mine..... 71	Homestake mills..... 29, 55
Golden Reward company 41, 42, 43	Homestake mine..... 27, 32, 36, 57, 72
Golden Reward chlorination plant..... 46	Homestake tailings..... 30, 56
Golden Reward smelter..... 25, 55	Hoodoo mine..... 25, 26
Golden Star claim..... 28	Hornblende district..... 27
Golden Star mill..... 29	Hvdliiff, M, R..... 54, 70
Golden Terra mill..... 29	Hydraulic mining..... 51
Gold Hill..... 33	
Gold Run..... 52, 71	
Gossan..... 58, 59, 63	
Grand Junction gold mine..... 21	
Grand View claim..... 79	
Graneros shale..... 13	
Granites..... 12, 15, 25, 67	
Granite range..... 24	
Graphite..... 20, 68	
Greenhorn limestone..... 13	
Green mountain..... 39, 45	
Griphite..... 68	
Grizzly Bear gold mine..... 22	
Grizzly gulch..... 51	
Grossularite..... 68	
Gustavus gold property..... 45	
Gypsum..... 13, 15, 43	

H

Haggin, J. B..... 28
Harney hydraulic company..... 51
Harney granite range..... 12
Harney Peak..... 12, 17, 18, 54, 67, 71, 72, 77
Harney Peak tin company..... 66, 70
Harrison gold mine..... 71, 75
Hat mound..... 62
Hayward..... 54, 64
Headen, W. P..... 66, 68
Hearst, senator..... 28
Heavrlan and Mulheisen..... 54
Hematite..... 43, 61, 62, 65
Heterosite..... 68
Hidden Fortune company..... 30
Hidden Fortune mine..... 37, 71
Hidden Treasure mine..... 32

I

Igneous rocks..... 37
Ilmenite..... 68
Impregnated Zones..... 27
Indians..... 17, 18
Indian affairs, commissioner of..... 17
Indian depredations..... 19
Indispensable claim..... 45
Ingersoll mine..... 68, 79
Inter Ocean mine..... 54
Iron..... 20, 43, 61 - 63
Iron carbonate..... 65
Iron Hill mine..... 46, 55, 64, 65
Iron mountain..... 62
Irving, J. D..... 38, 39, 44, 45, 48, 72, 73, 75

J

Jamesonite..... 64, 80
Jasper ore..... 62, 65
Jenney, W. P..... 17, 18, 22, 25, 52
Johnson Peak..... 37
Joint planes..... 49, 50
Jurassic..... 13, 15

K

Kellogg, L. D..... 28
Keystone 20, 23, 27, 51, 62, 64, 76, 79
Keystone gold mine..... 24
Keystone mica mine..... 75
Kidney siliceous ore..... 43
Kildonan milling company..... 46
Kiln roasting..... 46
King Solomon gold mine..... 22

L

	PAGE
Laccolites	37
Lakota formation.....	16
Laramie formation.....	13
Lardner, William.....	52
Last Chance mica mine.....	75
Lawrence county.....	19, 21, 22
Lead City.....	20, 28, 29, 55, 71, 72
Lead-silver deposits.....	63-66
Lepidolite	68
Leucopyrite	68
Lieberite.....	68
Lightning creek.....	54
Lime siliceous ores.....	21, 46-50
Limestone escarpment.....	12
Limestone plateau.....	12
Limonite	23, 43, 54, 62, 65
Lithium salts	80
Little Bud vertical.....	48
Little Rapid creek.....	53
Lost Bonanza mica mine.....	75, 76, 77
Lower contact	38
Lower quartzite.....	65
Ludlow, William.....	16

M

Magnesium.....	43
Majors, John.....	54
Mallory gulch.....	52, 54
Manganese	20, 63
Manty, Frank	53, 54
Mastiff copper property.....	58
May Flower gold property.....	22
McCoun, James	54
M'Gillycuddy, Dr.....	79
McKay, W. T.....	16
McMackin mica mine.....	75, 76, 77
McMasters, Samuel.....	28
McTigue, John.....	53
Metallurgical processes.....	57
Mica.....	20, 66, 75-77
Millard mica mine.....	75
Milling character of gold ores.....	55
Milling of tin ores.....	70
Mineral associates	43, 67, 78
Mineral Industry.....	65
Mineral paint works.....	63, 75
Mining & Engineering Journal.....	17
Mineralized Zones.....	21
Miners' Wax.....	43
Minnekahta limestone	13
Minnelusa formation	14, 63
Minnewaste limestone	13
Mint, report of director of.....	65
Miscellaneous minerals.....	80-81
Mitchell's bar.....	51
Moll, Samuel	54
Monarch mica mine.....	76
Montana gold property.....	22
Montana bar.....	53

Mulheisen (and Heavirland).....	54
Muscovite.....	68

N

Nahant	61
Nellie mica mine.....	75
Nemo	58
Newark mine	23
Newton, Henry	16, 17, 18, 22, 61, 62
Newton Jenney survey.....	17
New York mica mine.....	75, 76, 77
Nickel.....	59, 89
Nigger Hill	52, 53
.....	54, 67, 70, 71, 72, 74
Niobrara formation	13
Northern connected district.....	37
North Lead	37-39
North Star gold mine.....	22
Nuggets.....	53

O

Ochre.....	62, 63
Old Abe gold property.....	28
Old Bill gold property	22
Old Charlie gold property.....	22
Olive gold property.....	45
Olivenite	68
Opeche formation	13
Orthoclase	68
Output of Gold	56
Copper	61
Iron	61, 63
Manganese.....	63
Lead	65
Silver	65, 66
Tin	70
Tungsten.....	71, 75
Graphite.....	75
Mica	75, 76
Spodumene.....	79, 80
Output, summary of	81

P

Pactola	51, 58, 80
Pahasappa limestone.....	14
Palmer copper property.....	58
Palmer gulch mine.....	79
Pan-amalgamation	45
Pearce, Richard	43, 66
Pearson, J. B.....	28
Peerless mica mine.....	76
Pegmatite	67, 72, 76, 77
Pennington county.....	21, 22
25, 27, 57, 62, 63, 67, 76, 77	
Permian	13, 15
Perry	58
Perseverance gold mine.....	45
Petalite.....	68
Phonolite.....	12, 37, 38, 49

	PAGE		PAGE
Piedmont.....	20	Scorodite.....	68
Pierre shale	13	Scott, Samuel.....	62, 78
Pilgrim gold property.....	45	Seim pyrite mine.....	25
Pinney, Milton E.....	32	Sheeptail gulch.....	37, 39
Placers ... 19, 21, 34, 36, 50 - 54,	56	Sheridan.....51, 53,	57, 58
Platinum	54	Siderite	23
Plattner process	46	Siliceous gold ores.....	37, 50
Pleistocene.....	14, 21	Silurian	15
Pluma	46, 55	Silver.....11, 35, 43,	63 - 66
Poisoned Ox copper property	58, 80	Silver City.....	64, 80
Poplar gulch	52, 54	Sheeptail gulch.....	39
Porphyry..... 12, 25, 30, 64		Silver Ridge property	46, 47
Portland ..20, 37, 39, 41, 43, 45,	64, 80	Simmons, A. J.	66
Portland mining company.....	45	Sinking to quartzite.....	42
Potato creek	52, 53, 54	Sioux Indians.....	17
Potsdam	33	Sioux war.....	18
Pvrrhotite.....	30, 80	Slate breccias	25
Pyrite.....23, 24, 25, 26, 30,	43	Slavonian pyrite mine....	25
Pyrolusite	63	Slaty cleavage	15
Q		Sluicing	50, 51
Quartzite, sinking to.....	42	Smelter	25, 30, 55, 61, 64
Quartz porphyry	37 - 38	Smith, A. J., ...	45
Quartz veins..... 15, 21, 24		Smith, E. P.	17
R		Smith, F. C.....23, 37, 43, 44,	45, 47
Racine M and M company....	28	Spearfish	20
Ragged Top..... 37, 39, 47, 48,	50	Spearfish canyon	20
Railroads.....11, 19 - 20,	82	Spearfish creek.....29, 37,	50
Rainfall	14	Spearfish formation.....	13
Rapid City	14, 55, 80	Spearfish gold mining comp'y	18, 49
Rapid creek.....18, 50, 51, 53,	58, 62	Sphalerite.....	23
Rare minerals.....	81	Sphene	68
Red beds	15	Spinel	68
Red Canyon creek	63	Spodumene.....68, 77 - 80	
Red siliceous ores.....	42	Spokane mine.....	64
Reddy gold mine.....	71	Spring creek..... 18, 51,	58
Redfern	63	Spring gulch.....	32
Refractory ores	24, 37, 55	Squaw creek.....37, 39,	40, 42
Reimbold & company.....	79	Stamp mills	28, 29, 32, 33, 55
Reitz, O. A	71	Standby mine.....	27
Resume of mineral production	81	Stannite.....	67, 68
Reynolds, Joseph	21	Sterner vertical	48
Reynolds copper property....	58	Stewart mine.....	38
Rio Tinto copper property ...	58	Stibnite	43, 72
Riotte, E. N.....	69	St. John, E	53, 54
Rochford.....22, 27, 57, 63,	75, 80	Stockade, The.	17
Rockerville.....33, 36, 51,	52	Stream tin.....	69, 70
Rolker, C. M.	69	Structural materials (footnote)	9
Ross, H. N.....	16	Sugar Loaf hill.....	37
Ruby basin ..20, 37, 39 40, 42,	43, 55	Sugar Loaf laccolite... ..	40
Ruby gulch.....	54	Sula mine.....	71
Rutile	68	Sulphur.	43
S		Sulphide enrichments.....	59
Sand creek.....	52, 54	Sundance formation.....	13
Scheelite.....	68, 72	Sundance gold mine.....	39
Scolithus sandstone..	38, 39	Sunday fraction mine	79
T			
Tailings.....	30, 54		
Tallent, Annie D.....	21		
Tantalite..... ..54,	68, 69		

	PAGE		PAGE
Telegraph group.....	79		
Tellurium	43	V	
Terraville.....	29	Van Hise. C. R.....	23
Terry.....	39, 40, 42, 43	Veins.....	21, 20
Terry peak	37	Verticils.....	21, 40, 47, 48
Tertiary	12, 14, 15	Vigilante copper property....	58
Tetradymite	23	Vincent, C. M.....	69
Thomas, Capt.....	69	Vogesites.....	12
Thorson, Peter....	54	Vosburg, Theodore.....	66
Timber.....	82		
Tin	66-70	W	
Tin mountain vein.....	79		
Todd, J. E.	9	War Eagle hill.....	37
Tonalite	12	Warren mica mine.....	75
Topography	12	Wasp No. 2 mine.....	72
Tornado mine	41	Weed, W. H.....	59, 61
Tornado shaft	40, 42	Welcome mine.....	41
Tourmaline	68	Welcome mining company....	46
Treatment, methods of	55	West Virginia claim.....	64
Triassic.....	12, 13, 15	White Spar mica mine.....	75, 77
Triphyllite	68	Whitetail gulch.....	40
Triphite	68	Whitewood creek.....	50, 52, 55, 72
Trojan mine.....	45	Windy flats.....	58
Truax copper property.....	58	Window Light mica mine.....	75
Tungsten	71-75	Wing, "Doc".....	64
Twin peaks.....	48	Wolframite.....	68, 71-75
Two Strike mine.....	72, 73	Wood mine.....	79
		"Worm-eaten" sandstone....	38
U			
Ulke, Titus.....	68	Y	
Ulster mine.....	48		
Uncle Sam mine	22	Yellow creek....	37, 39, 50, 71, 72, 73
Union Hill mine.....	25, 26		
Union shaft	40	Z	
Unkpapa sandstone.....	13		
Upper contact.....	38		
Uranium	80		
U. S. geological survey	12, 82		
		Zircon.....	68

Date Due	



3 2044 102 944 956